Shared Innovation Space for Sustainable Productivity of Grasslands in Europe

Project Acronym: Inno4Grass

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Deliverable 5.3. Specifc grassland syllabus (D5.3.1) and power point presentations (D5.3.2) available for young farmers and advisors

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Grassland use in Europe

A syllabus for young farmers

Project partners of Inno4Grass

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Preface

The future of grassland farming in Europe is in the hands of young farmers. The topic grassland management has often been a weak point of teaching delivered by agricultural technical schools in several European countries compared with other topics. Training of future farmers and advisors could thus be significantly improved which could lead to better grassland management in the mid-term and long-term. For this reason, the European project Inno4Grass created a syllabus and a set of powerpoints on practical grassland management for the present and the next generations of grassland farmers and advisors. They can be downloaded at www.encyclopediapratensis.eu in the different languages of the countries participating in Inno4Grass. The syllabus and the powerpoints contain the necessary practical and technical knowledge required for sustainable grassland management.

The syllabus is written by a group of authors. By combining expertise of experts from the different partner countries of Inno4Grass, we were able to create a document that on the one hand provides general knowledge and on the other hand country-specific information and examples. Every part of this syllabus was authored by at least two people and reviewed by at least two other people, usually from different countries, to ensure that all relevant and available information was combined. It also ensured that the text is illustrated with examples from different European countries. Authors of specific parts of the syllabus are mentioned at the beginning of these parts. A full list of authors can be found on the next page. The preface of this syllabus further contains some general information about Inno4Grass and on the state of the art of European grasslands. Thereafter, the important general aspects of grassland management are presented in the different chapters: grassland production (Chapter 1), grazing management (Chapter 2), hay and silage making (Chapter 3), soil and nutrient management (Chapter 4), environment and biodiversity (Chapter 5) and quality of products from grass (Chapter 6). The syllabus ends with specific information on characteristics of the individual countries participating in Inno4Grass (Chapter 7).

We hope and expect that this syllabus will be a source of inspiration for (future) farmers and advisors.

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Inno4Grass – European thematic Network - Shared Innovation Space for Sustainable Productivity of Grasslands in Europe

Arno Krause and Talea Becker (Grünlandzentrum)

Kick-off Meeting Inno4Grass Project, Berlin

<u>Objectives of Inno4Grass</u>

European farmers and especially grassland farmers are facing tremendous challenges. On one hand they have to deal with instable prices for milk and meat and raising prices for inputs, on the other hand there are high society demands with regard to environmental protection and animal welfare. Grasslands are vitally important both for agriculture and society. Permanent and temporary grasslands cover 61 million ha across the EU-28 representing 16% of the total land area and 40% of the agricultural area in the EU (Eurostat, 2010). These grasslands serve multiple functions, including local provision of fodder for animal husbandry (and hence high-quality food provision for citizens), biodiversity conservation, carbon storage and provision of 'traditional' landscapes that European citizens appreciate for recreational purposes and cultural heritage. The large diversity of management practices, soils and climates enhance the range of ecosystem services provided by grasslands. Farmers in the EU often do not perceive the multi-functionality of grasslands as an advantage. This leads to undervaluation and a lack of valorisation strategies. Since market-oriented concepts to create rewards for ecosystem services have not yet been sufficiently developed or understood, their multi-functionality turns grasslands, especially in intensive production systems, increasingly into areas of conflict between food demand and calls for the provision of other ecosystem services. The potential for a better use of grassland for reducing production costs in livestock farming has also been underestimated.

In order to cope with the challenges and to valorize the advantages of grassland better, farmers need dedicated innovations, which help them to improve grasslands economic performance. It is important, that these innovations have not only been developed and tested in scientific institutions. Farmers need innovations, which have been used on practical farms and which are adapted to the conditions on farms.

Several reasons explain the low adoption of innovations in grasslands:

i) grassland-based production systems are complex and therefore innovative systems must be implemented as a combination of innovative practices that show a dependency to local conditions
ii) innovation benefits from grasslands are apparent after a time lag
iii) grassland innovation affects the various aspects of sustainability (profitability, environment, social acceptance) and often in a contradictory manner
iv) limited and sometimes no interaction between practice and research.

Despite this problems, some farmers are very innovative – especially the early adopters, they develop solutions and techniques on their own or adapt existing ideas to the conditions of their farm. It takes time, until these innovations and techniques are spread among the community of farmers, sometimes they do not move out to all the community. The collaboration between farmers, advisors and scientists is insufficient in the countries concerned. For this reason the latest results of research are not sufficiently put into the practice and valuable knowledge related to grassland is discovered by practitioners at a late stage.

The aim of Inno4Grass is to overcome these issues and to foster the collection, spreading and creation of knowledge. The overall objective of Inno4Grass is to close the gap between practice and science and to collect innovations, which would be ignored otherwise and to ensure implementation of innovative systems on productive grasslands. The long term goal of the project is to increase profitability of European grassland farms and to preserve environmental values. Apart from collecting innnovations, Inno4Grass facilitates the process of co-creation of knowledge. For this, Inno4Grass brings together farmers, scientists, advisors and teachers to develop solutions for typical problems and for adapting existing ideas to practical farms. These groups are moderated by Facilitator Agents, which facilitate the communication and the exchange between the members of the groups. They initiate discussions on innovation in a participatory approach using electronic discussion groups and farmer's networks. Inno4Grass fosters the exchange of ideas within eight European member states. Inno4Grass is an international project, the following Member States are part of the project: Belgium, France, Germany, Ireland, Italy, Poland, Sweden, the Netherlands. Within the project there are meetings of the Facilitator Agents and cross visits of farmers between countries to foster the cross-border flow. So, the project benefits from the diversity within the farmers population.

The innovations discovered in the project are spread among the community of farmers. All innovations gathered in the project are documented with farm portraits and can be found on the homepage of the project https://www.inno4grass.eu/en/dissemination. Apart from this syllabus further dissemination material is prepared: (innovation , abstracts, video clips, leaflets) and used for the enrichment of national and European Wikimedia and the Encyclopedia Pratensis (https://www.encyclopediapratensis.eu).

Diversity of European grasslands

Alain Peeters (RHEA Research Centre) and Johannes Isselstein (University of Göttingen)

The vast majority of European grasslands are man-made. They have developed concomitantly with livestock husbandry. European grasslands are extremely diverse with regard to their management, soil types, plant composition, production potential and fodder quality. They can be divided in two main categories: permanent and temporary grasslands (Peeters *et al*., 2014).

Main grassland types

Permanent grasslands are grasslands that have not been completely renewed after destruction for ten years or longer. They can be agriculturally-improved, semi-natural, natural or no longer used for production. They can be species-rich or species-poor. They comprise grasses, legumes, forbs, and grass-like plants in variable proportions. Trees and shrubs can be present, for instance in grazed wooded areas.

Agriculturally-improved permanent grasslands are located on soils with a moderate or high fertility that allow for an intensive agricultural management. Compared to semi-natural grasslands the fertilization is higher, the stocking rates are higher, the swards are defoliated more frequently and, have a higher herbage and livestock production.

Natural and semi-natural grasslands are low-yielding permanent grasslands, dominated by indigenous, naturally occurring grass communities, other herbaceous species and, in some cases, shrubs and/or trees. These mown and/or grazed ecosystems have not been substantially modified by agricultural practices. Natural grasslands are rather rare in Europe, they occur spontaneously in marginal environments such as mountain tops, tundra, or salted soils. Semi-natural grasslands are related to human activities, without human intervention most of them would be colonized by woody vegetation.

Temporary grasslands are grasslands that are sown with forage species that can be annual, biennial or perennial. They are sown on arable land and can be integrated in crop rotations or sown after a preceding grass crop. They are kept for a short period of time, from a couple of months to usually a few years. They are usually established with pure sowings of legumes, pure sowings of grasses or grass/legume mixtures.

Economic and social importance of European grasslands

Permanent grasslands are an important component of European landscapes and farming systems. They cover about 60 million ha in the European Union (EU-28, 2013). Temporary grasslands cover about 11 million ha. Together, they occupy about 40% of the European Utilized Agricultural Area (UAA) (Eurostat).

These grasslands are the feeding basis of about 196 million heads of grazing livestock. They are managed by about 3.6 million holders, i.e. about 33% of all European farm managers (Eurostat: EU-28 in 2013). There were about 134 million

Livestock Units (LU) of total livestock and 78 million LU of grazing livestock (59%) in the EU-27 in 2007. The vast majority of them were located in the EU-15. In the grazing livestock population (in LU) in the EU-27, 82% were cattle and 14% small ruminants (sheep and goats). Dairy cows accounted for 31% and other cows (mainly suckler cows) for 16% in the total LU of grazing livestock. Two thirds of cows were thus dairy cows, one-third other cows. Beef and veal, sheep and goat meat amounted to 11% and milk to 14% of the total agricultural production value (Eurostat).

Grasslands are essential for feeding livestock and eventually for supplying milk and meat to human populations. They are the cheapest source of feed to supply grazing livestock and can thus contribute to reducing production costs. Grass-fed milk and meat have unique nutritional properties for consumers, that are sometimes highlighted by certified trademark such as ‘Pasture for Life’ in the United Kingdom.

Milk can be processed within the farm in a diversity of products such as butter, cheese, yogurt, and ice cream. Meat can also be processed, usually by butchers, and sold by farmers as meat parcels or delicacies. These products can be sold in short and local marketing chains which has the potential to significantly increase farmers’ income and create jobs in agriculture.

Environmental importance

In Europe, agriculture has created over centuries a patchwork of habitats very favourable to the flourishing of biodiversity. For instance, extensive grazing in common lands and haymaking in meadows have created diverse semi-natural ecosystems and attractive landscapes. These semi-natural grasslands are among the most species-rich habitats of the continent. Even intensively used permanent grasslands, although less diverse in terms of plants and insects, provide more ecosystem services than arable crops. Grasslands play indeed a very important role for conserving European biodiversity, creating attractive landscapes including for tourists, storing carbon in soils, improving soil fertility, protecting soils from erosion, and surface and ground water from nitrate and pesticide pollutions.

Threats

Permanent grasslands are threatened. In the EU-6 (Benelux, France, Germany (GFR), Italy), permanent grassland losses are estimated at about 30% and 7 million ha between 1967 and 2007 (Eurostat). In Upper Normandy (France) the permanent grasslands area was reduced by about 50% between 1970 and 2000.

1. Grassland production

1.1 Characteristics of grass

Alain Peeters (RHEA Research Centre) and Nilla Nilsdotter-Linde (Swedish University of Agricultural Sciences)

Grass seeds include the coleoptile (shoot sheath), the scutellum, the radicula and the coleorrhiza (root sheath) (Figure 1.1). The scutellum is homologous to the leaf lamina of the cotyledon and the coleoptile to the leaf sheath of the cotyledon. Coleoptile and coleorrhiza are membranes that respectively protect shoot and leaf meristems and the radicula during the first step of the germination process when these fragile organs have to find their way through the soil. When seed germinates, it produces first the radicula, the first root, that quickly absorb water and nutrients. Then, the coleoptile is pushed upward, it elongates, reaches the soil surface, and the first leaf emerges from it. Side roots are produced quickly around the primary root. When the first three leaves are deployed, a bulge appears just above the seed and below the soil surface. It is the tillering plateau from which all secondary roots and aerial tillers are produced. Primary roots and seeds disappear afterwards.

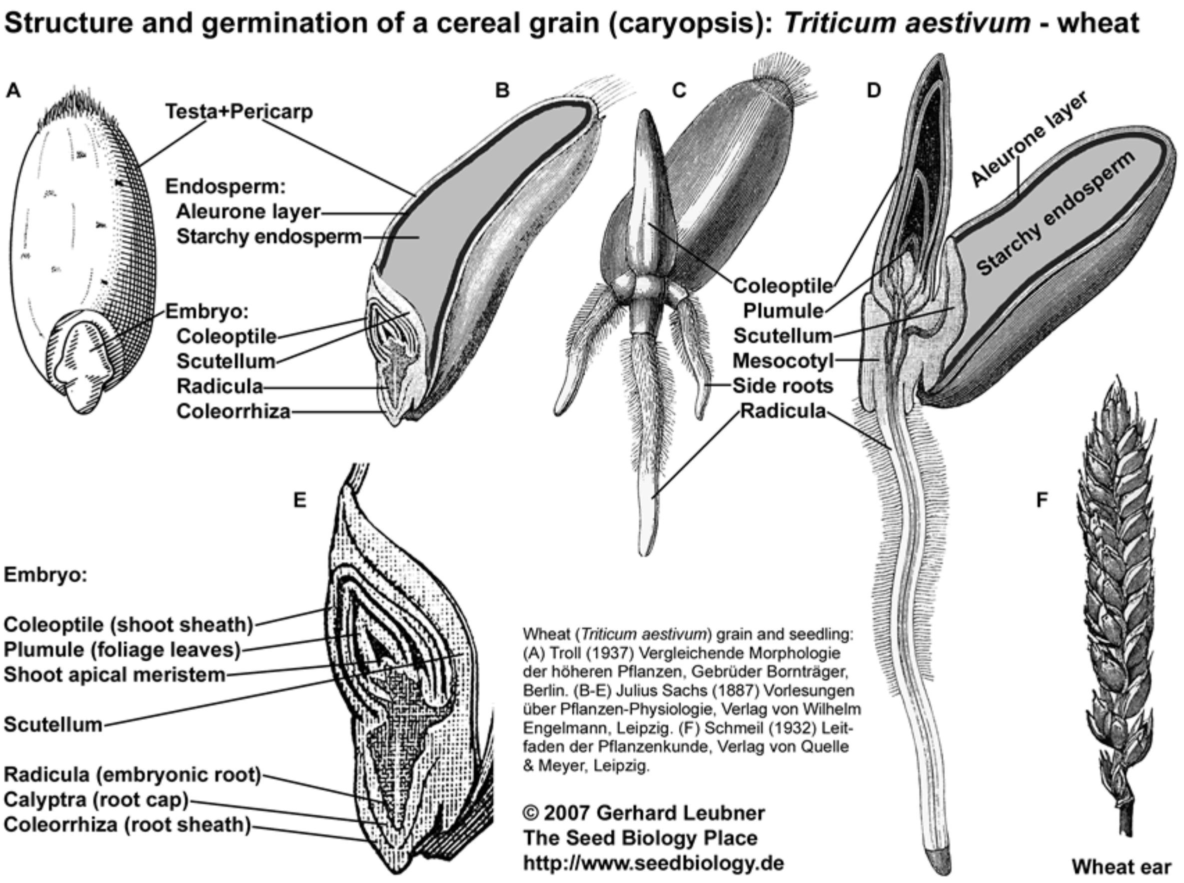

Figure 1.1. Seed anatomy (The Seed Biology Place, 2019).

Grass leaves are made of three sections: the upper part of the leaf, the most visible because it usually detaches from the stem, is the lamina or blade, the lower part of the leaf, the sheath, encircles the stem (Figures 1.2 and 1.3). At the intersection of the lamina and the sheath, there can be two organs, auricles and ligule. Auricles are often claw-like appendages which tend to clasp the sheath. The ligule is an extension of the sheath at the base of the lamina. Its axis is parallel to the stem and thus perpendicular to the lamina. It may prevent water penetration between the sheath and the stem which could cause stem rotting. Tillers are the equivalent of branches of woody species. A tiller appears at the internal basis of a leaf sheath. Each tiller can again produce leaves and new tillers at the basis of these leaves. Tillering is thus theoretically exponential, but it is of course limited by light, nutrient and water resource availability. After germination, when four leaves are visible on the main tiller, there is a moment when two secondary tillers appear at the basis of the two first leaves. The full **tillering phase** is then reached.

During the vegetative phase described above, all meristems are located just below or just above soil surface. They are thus well protected from herbivore teeth. This confers to grasses a unique capacity to regrow quickly after defoliation compared to many dicotyledons. These plant species are thus well adapted to herbivore presence and activity. Actually, these two plant and animal species groups co-evolved and need each other's. Most dicotyledon species are not so well adapted to grazing because a large part of their meristems is located well above soil surface. They can thus be easily destroyed by grazers. A sward grazed by herbivores is thus often dominated by grasses. In a way, herbivores 'weed' herbaceous swards by reducing the proportion of dicotyledon species. Grasses in return produces a lot of nutritious leaves for rewarding herbivores for this service. Grasses do not try to escape from the action of grazers by producing toxic compounds or mechanical defence organs like many dicotyledon species do, on the contrary they encourage herbivores to graze them.

Stems can be produced on each tiller. A stem bears leaves and an inflorescence on its top. Some species requires a period of frost (vernalisation) for inducing the reproductive phase and stem elongation. Some others can enter into the reproductive phase soon after the tillering phase. These stems are emerging from the tillering plateau, at the interface of roots and aerial organs. They are made of nodes on which leaves appear and internodes, the space between two nodes. Internodes are first very short. The first internodes start growing and push the stem upwards a bit like a radio antenna, but, in grass, it is the basis that elongates first. It is the **internode elongation phase**. When the first internode is about to reach its full length, the second internode, located above the first one, starts elongating too. It is the **stem elongation phase**. The process continues with the following internodes till the apparition of the last leaf that emerges from the sheath of the previous leaf. This last leaf is called the flag leaf. Soon after, the inflorescence emerges too. It is the **heading phase**. When the inflorescence is completely deployed, etamins go out from the flowers. It is the **flowering phase**. When seeds are formed, the plant has reached the **fructification (seed forming) phase**.

Grass inflorescence can be spikes or panicles. Spikes are contracted inflorescence like the one of wheat (*Triticum aestivum*) or ryegrasses (*Lolium* spp.). Spike ramifications are very short. Panicle ramifications are much more developed and visible such as the one of oats (*Avena sativa*), fescues (*Festuca* spp.) or meadow grasses (*Poa* spp.). Inflorescences are made of spikelets that can contain one or several flowers. Each flower can produce a seed.

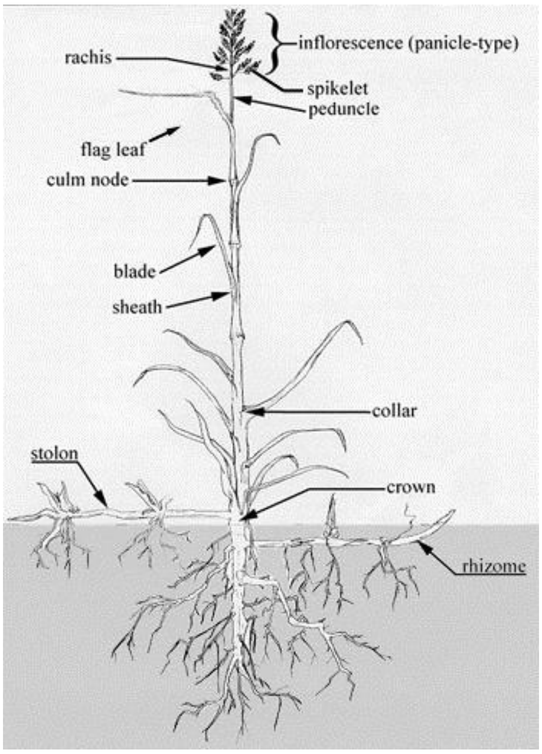

Figure 1.2. Grass anatomy

(Oregon State University, Forage Information System, 2019)

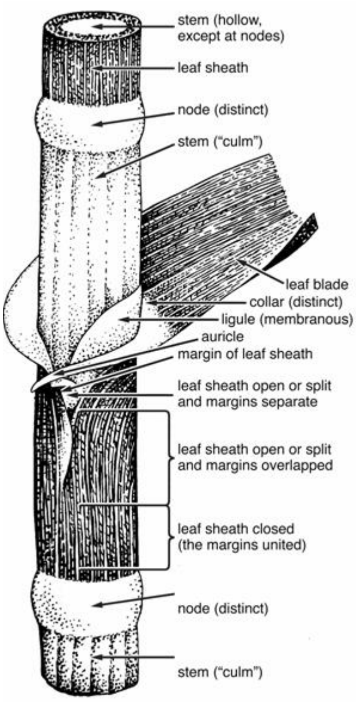

Figure 1.3. Leaf characteristics (Ministry of Agriculture, Food and Rural Affaires, Ontario, 2006)

Most grasses make compact tiller tufts such as ryegrasses (*Lolium* spp.) or cocksfoot (*Dactylis glomerata*). Some produce creeping stems that grow above the soil surface, the stolons (Figure 1.2). An example is creeping bentgrass (*Agrostis stolonifera*). Some others produce rhizomes that are stems growing horizontally below the soil surface such as couch grass (*Elytrigia repens*). Stolons and rhizomes are efficient means of vegetative reproduction. Plants equipped with these organs can easily spread in a sward.

Grass growth can be described for a single uninterrupted growing period or for several growing periods. It can be expressed as a production or yield which is the amount of biomass per surface unit (usually presented in kg of dry matter (DM)/ha) or as growth rate that is the production per time unit (usually presented in kg DM/ha x day).

Figure 1.4 shows an example of the evolution of dry matter production (Y axis) over time (X axis) during an uninterrupted grass growth cycle. Four phases can be distinguished in this growth cycle. At the beginning of the cycle, for instance at the end of winter or after seed germination, grass growth is very slow (phase I). After 10 days on the figure, growth becomes very fast (phase II). This period lasts for 20 days on the figure (from day 10 to day 30). It is extremely fast between the 10th and the

20th day, then the growth curve passes through an inflexion point and it slows down a bit. In phase III, growth is almost nil, production reaches a maximum. After the 50th day on the figure, growth is negative, production decreases (phase IV).

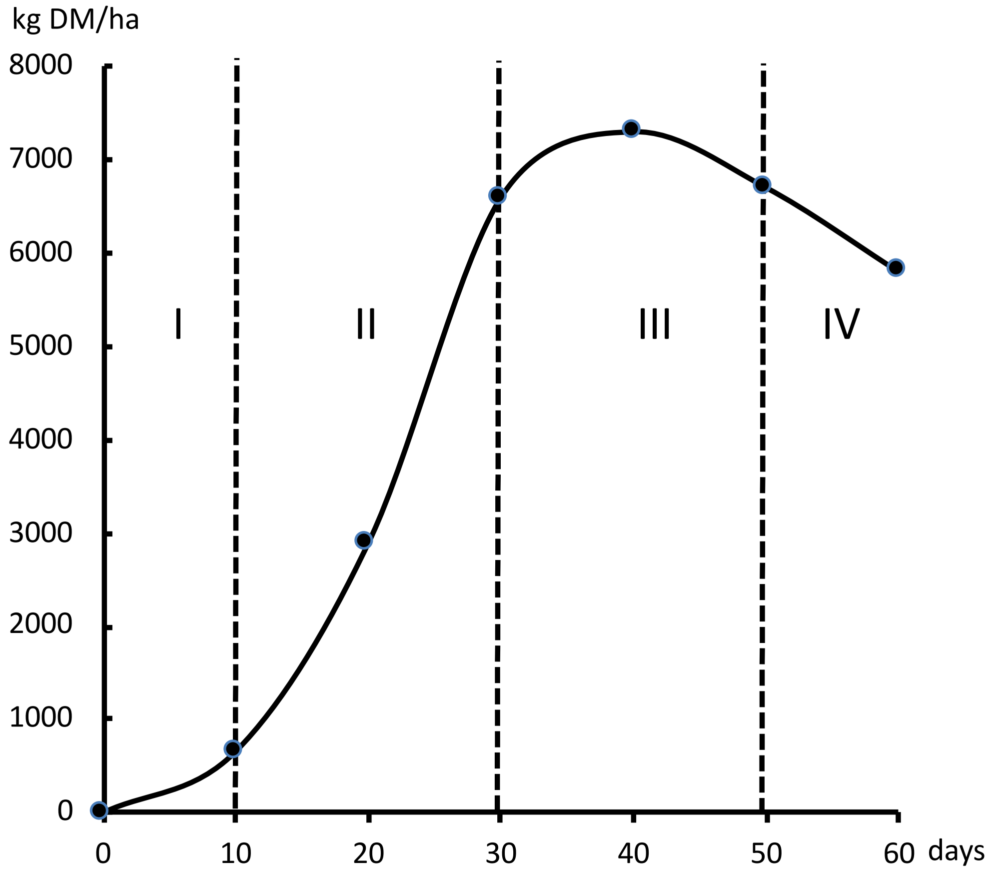

Figure 1.4. Evolution of dry matter production over time during an uninterrupted grass growth cycle (Peeters and Wezel, 2018).

This curve is exponential during phase I and the first part of phase II. It can be described as a Mitscherlich curve till the middle of phase III. The four phases of Figure 1.4 are common to many living beings. They correspond to juvenile, youth, adult and senile phases.

At the beginning of the growing period, plants have to mobilise their nutrient resources that can be either stored in seeds or in plant organs (stem basis and roots). These resources, notably carbohydrates, are used for building new photosynthetic organs, leaves in priority. In the beginning of phase II, plants have produced a leaf area that can absorb enough solar energy to become independent from nutrient storage. At the inflexion point of phase II, plants produced so much carbohydrates that they were able to replace all nutrient resources consumed in phase I. A grass sward should thus not be defoliated by grazing or cutting before this point otherwise plants will be weakened, especially if the same process happens in the following growth cycles. This could eventually lead to plant death. In the second part of phase II, plant production is still increasing fast. In phase III it is clear that the best cutting time is exceeded. There is no biomass accumulation anymore. In phase IV, a part of plant biomass is lost because of leaf and stem senescence. These old organs lose weight, their nutrients are transferred to younger organs. They become pale green, yellow and finally brown. Eventually they detach from their plant and fall down on the soil surface where they are recycled by soil organisms. This role is fulfilled mainly by earthworms, bacteria and fungi.

The regrowth cycle initially relies on the energy reserves that plants store as carbohydrate in the basal stems. Immediately after grazing, plants rely on these to provide energy for regrowth until the first new leaf is produced (Figure 1.5). With the first new leaf, photosynthesis then becomes the main energy source for growth of subsequent leaves, as well as replenishing carbohydrate reserve stores. Reserves are restored when plants have produced three new leaves.

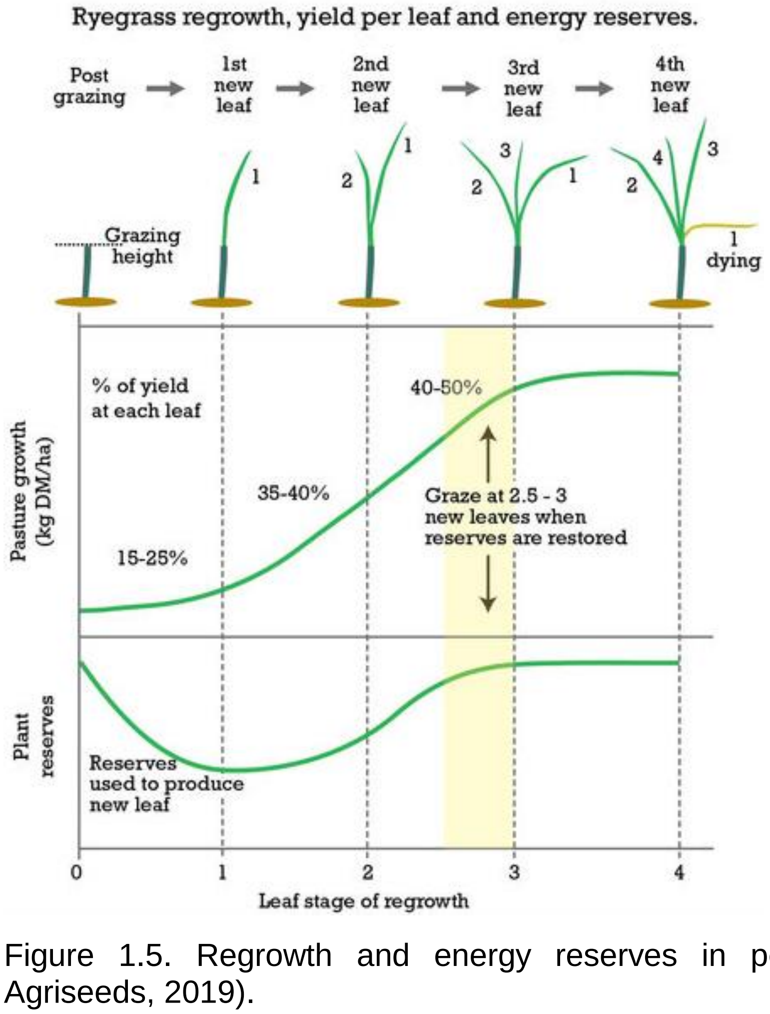

Figure 1.5. Regrowth and energy reserves in perennial ryegrass (Barenbrug Agriseeds, 2019).

Figure 1.6 presents a similar yield evolution curve. It describes also the evolution of physiological stages. In phase I, plants are in the vegetative phase. Above ground, they are only producing leaves. In the first part of phase II (before the inflexion point), they are starting to produce also stems. It is the internode elongation stage quickly followed by the stem elongation stage. Early heading corresponds to phase III and seed forming to phase IV.

Figure 1.6 also shows the evolution of forage quality in parallel to the evolution of grassland yield. Grass quality covers several parameters among which the most important are digestibility, net energy, protein, carbohydrate (soluble carbohydrate, cellulose, and hemicellulose), lignin, macro- and micro-element contents. A good forage for demanding livestock types is highly digestible and contains high levels of protein, energy and minerals and low lignin levels. When plants grow, the proportion between cell content and cell walls decreases. Since cell contents contains more nutrient than cell walls, quality decreases. During grass growth and development, the proportion of leaves decreases to the benefit of stems. Stems are less digestible than leaves because their lignin content is higher. Forage quality evolves thus in an opposite way to yield. When yield increases, forage quality decreases. A compromise has thus to be made between forage quantity and quality for feeding livestock. This compromise is reached in spring at about the internode elongation stage or the beginning of stem elongation. When a sward is grazed at these stages, many stems are also destroyed and regrowth is leafy in some grasses and thus more nutritious. In summer and autumn, these grass species produce only leaves. The ideal grazing stage is thus vegetative.

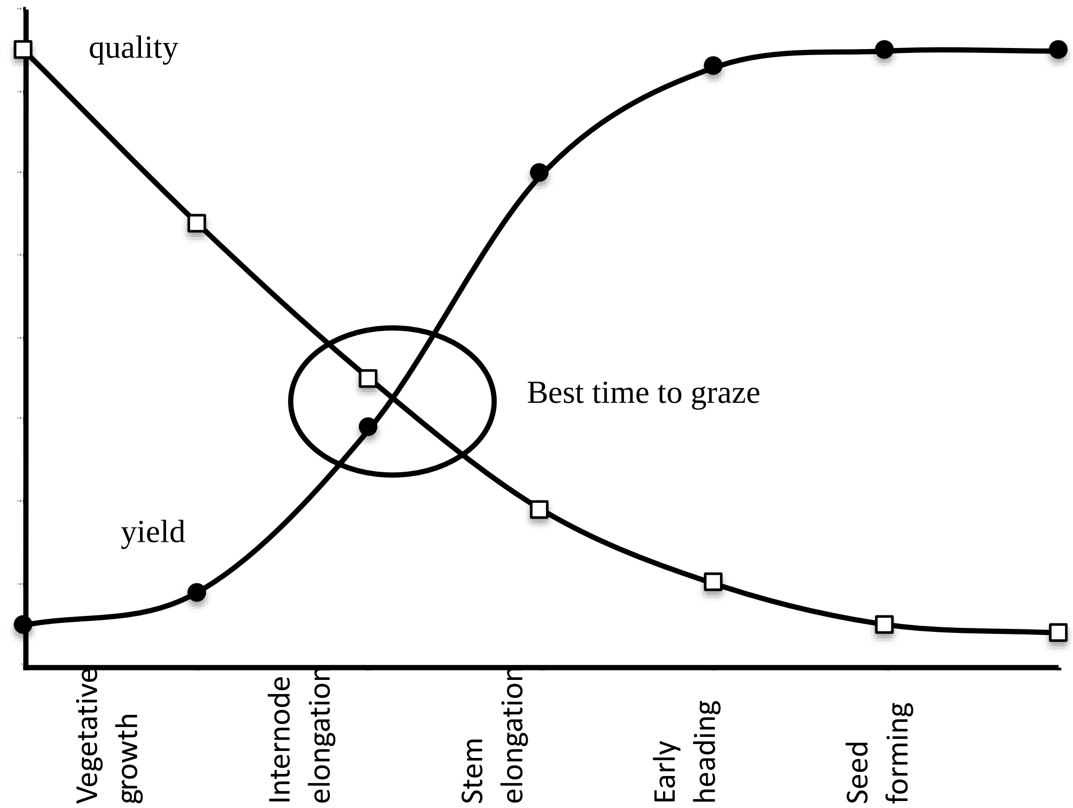

Figure 1.6. Evolution of dry matter production and forage over time during an uninterrupted grass growth cycle (Peeters and Wezel, 2018).

The production equation can be derived for calculating growth rate. If growth rate is calculated for the data of Figure 1.6, growth rate curve has a clock shape with a maximum at the inflexion point of phase II. This means that growth rate is accelerating from the beginning of phase I and is decreasing after the inflexion point for reaching 0 in phase III and becoming negative in phase IV.

Figure 1.7 shows a sward growth rate evolution between March and November in an Atlantic climate of North West Europe. This camel back curve has two maxima. The first and the most important one is noted in May when growth rate can reach 160 to 180 kg of DM produced per ha and per day. At that period of the year, in a single week, up to one ton of DM can be accumulated per ha. May is the period of the elongation phase. It is the middle of the reproductive phase of most grass species. When most stems are destroyed by successive defoliations, growth rate goes down. This decline is reinforced by summer water deficit. The curve reaches then a minimum, usually in August. After summer drought, autumn rains stimulate nitrification in grassland soils. These two factors combined, water and nitrogen availability, revive plant growth. In September, a second but smaller maximum is reached. However, temperature and solar radiation are quickly limiting and growth rate declines again. In continental climates growth rate is totally stopped in winter. In hyper-Atlantic climates such as those of Ireland, south east England or Brittany, grass growth never totally stops in winter, but it is of course very low.

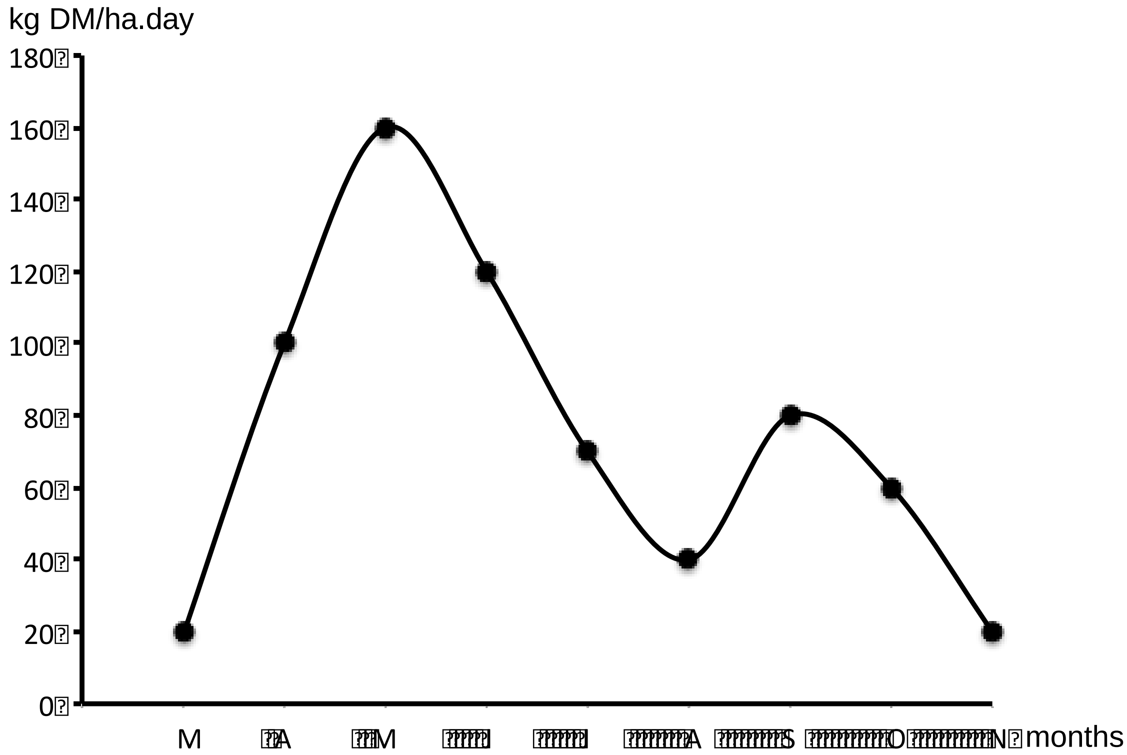

Figure 1.7. Example of an evolution of sward growth rate over a full growing period from March to November in an Atlantic climate of North West Europe (Peeters and Wezel, 2018).

Grassland vegetation not only includes grasses. Permanent grassland can also host legumes and other forage plants. This last category includes non-leguminous dicotyledons (mostly *Apiaceae, Asteraceae, Caryophyllaceae Lamiaceae, Plantaginaceae, Ranunculaceae, Rosaceae, Scrophulariaceae*) and grass-like plants (e.g. sedge (*Carex* spp.) and rushes (*Juncus* spp.)). Even temporary grassland can exhibit a certain plant diversity. Grasses and legumes are usually dominant, but plantain and chicory are more and more frequently used as forage plants too and several spontaneous species may appear in the sown sward.

Non-leguminous dicotyledons have been for long considered as weeds and chemically destroyed. Many are currently recognised as forage plants that can bring nutrients and secondary compounds that are beneficial to livestock. They may also increase forage intake by animals. Common dandelion (*Taraxacum* spp.) is an example of these valuable forage species. However, in permanent grasslands, a balance between the proportion of grasses, legumes and other species should be targeted. There is no optimum, universal balance but the following proportions can be cited as one possible example: 60% grasses, 30% legumes and 10% other forage plants. A legume content of 30-50% is recommended for increasing livestock intake according to different studies.

1.2 Use of grass

Alain Peeters (RHEA Research Centre) and Nilla Nilsdotter-Linde (Swedish University of Agricultural Sciences)

Permanent grasslands often occupy in priority plots that are considered regionally as marginal *i.e.* plots that cannot or not easily be used for annual crops. Soils can be superficial, too stony, too wet, too dry, or nutrient poor. These plots can also be located on steep slopes or in remote places in relation to farm buildings.

They can also be placed in priority close to cow sheds in the case of dairy cows even if these plots are located on very good, deep and nutrient rich soils. Long moves between milking place and grazing land should indeed be limited as much as possible for dairy cows.

Permanent grasslands are often grazed in regions where grazing is traditional.

In intensive dairy systems, when the grazing area close to farm buildings is not limited, permanent grassland plots can be alternatively used for grazing and cutting. In this case, cuts are mainly conserved as silage. This alternation between grazing and cutting has several interesting properties. If cuts are taken at the right time, it may control perennial weeds by preventing seed formation of docks (*Rumex* spp.), thistle (*Cirsium* spp.) and nettle (*Urtica* spp.) for instance. Cuts are followed by urine and dung-free regrowths that are more palatable for grazing animals. These regrowths are clean from livestock internal parasites. Refuses of the previous grazing episodes, mainly stems, are harvested by cuts which produces a fresh leafy sward afterwards. Cuts are taken after a longer regrowth period than grazed grass. This is favourable to the restoration of nutrient storage in shoot basis and roots of grassland plants. At the opposite, grazing makes sward denser, maintains short sward heights that are favourable to the persistence of white clover and some grasses, and fertilises plots by urine and dung.

In beef systems and in the case of heifer, permanent grassland plots are mainly grazed, rarely cut. They can be located at some distance from farm buildings since animals must not come back every day to a barn. They can stay in the same location for several months, moving or not from one plot to another.

In regions where grazing is not traditional, where animals are kept indoors during the whole year, permanent grasslands can be exclusively cut for harvesting fresh grass, or for silage or hay. However, this management type induces a degradation of sward quality over time, especially in case of late cuts. Forage exports have also to be compensated by organic or inorganic fertilisation for avoiding soil nutrient depletion. This system is also more expensive compared to grazing systems where animals harvest grass themselves, while in zero grazing systems and in the case of conserved grass, forage must be cut, possibly dried out, transported by mechanical means and distributed fresh.

Permanent grassland vegetation is the result of the many interactions between soil, climate and farmer's management. It is thus highly variable throughout Europe. Permanent grasslands can be agriculturally-improved, semi-natural, natural or no longer used for production.

Temporary grasslands can be either grazed, cut or mixed use.

There is however a clear trend to use them for winter forage production in complementarity to grazed or mixed used permanent grasslands. They are often included in crop rotations with annual crops. Temporary grasslands can be sown with pure grass, pure legume or grass/legume mixtures. Innovative mixtures based on plantain, chicory, white and red clovers for instance are developing for specific uses. Pure grass mixtures are usually fertilised. They can include one or several species of the following grasses: perennial, Italian and hybrid ryegrasses, tall fescue, meadow fescue, timothy, or cocksfoot. Ryegrasses are usually dominant in Atlantic climates. Pure legume mixtures are rarer and often located in the south of Europe. Pure lucerne or pure sainfoin for instance can be noted in some southern situations. At the opposite, grass/legume mixtures are very common. Examples of simple mixtures are: cocksfoot/lucerne, ryegrass/red or white clover, cocksfoot/red clover, timothy/red clover. More complex mixtures can include perennial ryegrass/meadow fescue/timothy/red and white clovers. Many solutions are possible.

Temporary grasslands can also be grazed and occasionally cut. A typical situation is often encountered in North-West Europe where a temporary sward is resown every 4 to 5 years with perennial ryegrass mixed or not with other grasses and white clover. It is thus not included in a crop rotation. It can however be established on very good, deep and nutrient rich soils. This sward type is often grazed by dairy cows, less frequently by suckler cows.

Mainly cut temporary grasslands can be used for extending the grazing season in complement to permanent grasslands. Red clover/grass mixtures start growing earlier than permanent grasslands in spring. They can for instance be grazed at that time for about two weeks with an electric wire. Then the animals are moved to permanent grassland plots where they graze till mid-October or so while temporary grasslands are cut for instance three times for silage making. In North West Europe, when permanent grasslands stop growing in autumn, animals can graze again temporary grasslands till the end of December or January according to location and weather conditions. This technique can dramatically reduce winter feeding costs by reducing the housing period from 6 to 3 months for instance. However, grazing on wet soils in early spring and late autumn requires caution for not damaging sward and soil structure. The further north, the more important it is also to consider the effect of late autumn grazing on winter survival. Late defoliation decreases the reserves of carbohydrates needed for winter survival, if there is no time for regrowth before the winter arrives.

Exclusively grazed grasslands can be permanent or temporary. They are though mainly permanent and grazed by suckler cows or heifers. They can also exist in dairy cows system when grazing area is limited around farm buildings. Dairy cow plots are then exclusively grazed. These plots can be permanent or temporary grasslands.

In the past, in traditional extensive systems, specialized cutting grasslands existed everywhere. They were cut once for hay in summer and then the small regrowth was usually grazed in September. They were located on a diversity of soils, very acid, calcareous or wet. Their vegetation was among the most diverse of all European terrestrial vegetations. They were progressively abandoned and are now threatened and a topic of nature conservation concern.

In conventional farming, **exclusively cut grasslands** are mainly temporary. An exclusive cutting regime has indeed a negative influence on sward quality. In 2 to 3-year temporary grasslands for instance, this effect is acceptable while in permanent grasslands it leads to strong sward degradation after a couple of years. However, exclusively cut permanent grassland can still be sometimes encountered, particularly in large wet valleys where soils are too wet in spring to be grazed. The first cut is then taken later when soils are better drained and allow for tractor traffic. If these plots are also remote from farm buildings, the other regrowths can also be harvested by cutting. This situation prevails in the East of Poland for instance. Foxtail (*Alopecurus pratensis*) or couch grass (*Elytrigia repens*) are often the dominant grasses in these conditions.

Mixed used grasslands are very common either in permanent or temporary grasslands. Most extensive systems combine for instance a hay cut with several grazing episodes. Most intensive systems, usually associated to dairy systems, may combine several short grazing periods with one or two silage cuts. As explained above, the alternation of grazing and cutting is a very beneficial system for both grassland plants and grazing animals.

1.3 Grassland species and sward assessment

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Factors affecting the botanical composition

Grasslands provide ecosystem functions, for example carbon sequestration, nitrogen fixation (if legumes occur in the sward), preservation of water quality, biodiversity conservation, positive effects if integrated into a crop rotation (prevention of weed infestation in arable crops), cultural aspects and the provision of forage for ruminant livestock production. Due to a wide range of climates (sub-tropic to sub-arctic, from mountainous to the lowlands), grasslands appear in diverse botanical compositions. The number of species is mainly mediated by the management intensity and can range between few species in temporary grasslands and up to very high numbers (e.g. about 70) in extensively managed grassland. Moreover, the magnitude of these compositions is driven by the management intensity (fertilisation, defoliation frequency) and all other agronomical measures (e.g. cut *vs*. grazed, over- and re-sowing) at a specific site. Each species has its own demand with respect to the management and site conditions and a sustainable sward is only as good as it is managed, because the grassland sward is a result of several interacting factors (Figure 1.8). In fact, all of them directly or indirectly also affect the competition between species, which is an underlying main driver of changes of the botanical composition over time. Site conditions are the basis and preconditions of productivity under the given environment, as they affect the plant growth (climate, meteorology, soil properties) and the mechanisation potential (topography). Usually, they cannot be changed by the farmer. Utilisation form, fertilisation and sward care depend on the agronomical choices of the farmer. The utilisation form refers to the management of each site. There are farms which predominantly cut their grass, others graze it and some do both. Intensity refers to the number of cuts per year or the grazing intervals on one site. Under cold climates, the timing of the first and the last cut influences the winter survival and the botanical composition of the sward. Nutrients affect the soil fertility and thus the productivity up to a certain point. With increasing nutrients availability, species taking most advantage of fertilisation tend to become dominant. Over-fertilisation does not further increase forage yield and results in species-poor swards with little biological and agronomical value. Under sward care the operations periodically carried out to maintain good conditions of the swards are addressed (i.e. resowing or rolling in spring). Concerning sward renovation, the composition of the seed mixture greatly affects the botanical composition of young swards, while grassland management becomes more and more important by time. The sward botanical composition is consequently a result of complex interactions.

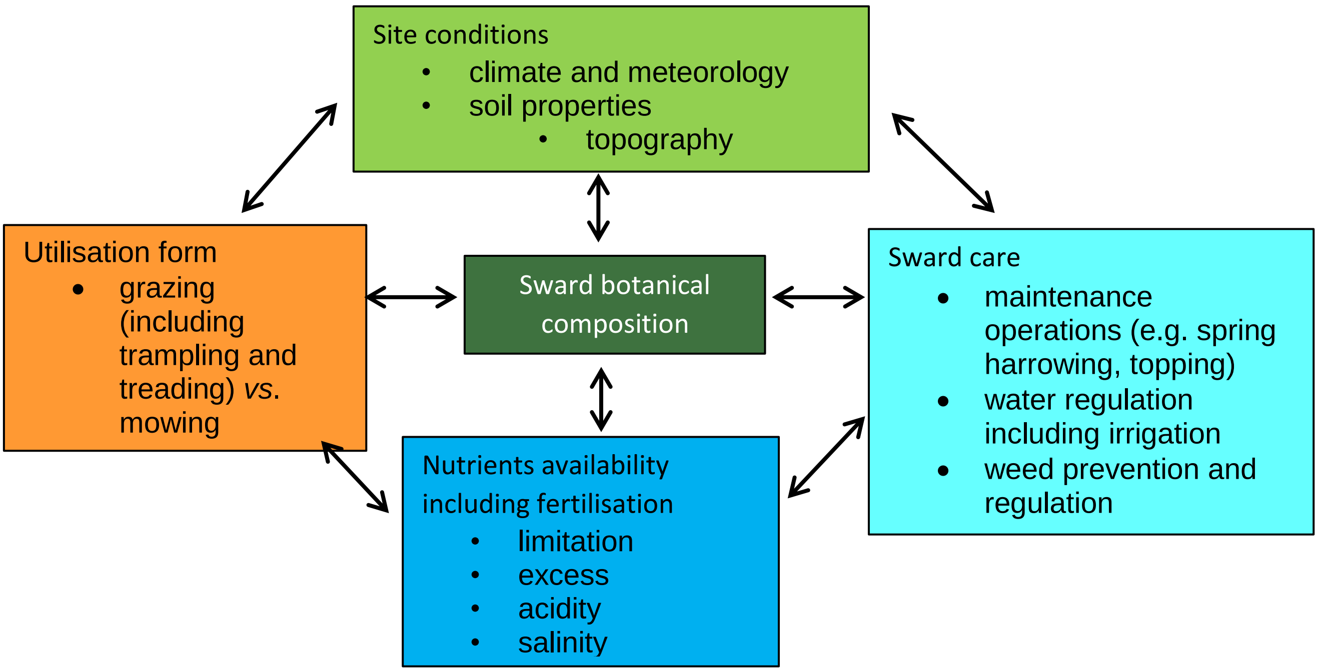


Figure 1.8. Factors affecting the botanical composition of the sward (adapted from Voigtländer and Jacob, 1987).

Grasses, legumes and forbs

The most important functional groups of species in a grassland sward are represented by grasses, legumes and forbs (herbaceous, mainly dicotyledonous species being neither grasses nor legumes), all of which are more or less likely to occur in forage production. Examples of common forbs in grassland swards for dairy production are dandelion (*Taraxacum officinale*), plantain (*Plantago lanceolata*) or common chickory (*Cichorium intybus*). Shrubs, bushes and trees mostly appear at the edges of pastures, spontaneously in the swards or organised in agroforestry systems, and represent a feeding source for browsing animal species (i.e. sheep and goats).

Grasses are able to tiller, viz. to generate secondary tillers from tiller buds. Tillering is stimulated by defoliation (mowing, grazing) and the position of the tiller buds determines the growth form of grasses. Grasses with aboveground upright/erect growing tiller buds form tussocks, while grasses with belowground tiller buds (turf-forming) are particularly efficient in building dense swards (Table 1.1). Some species, moreover, have a pronounced creeping habit due to specialised tiller buds enabling horizontal growth (stolons if growing above-ground and rhizomes if growing below-ground) and are specialised in colonising bare ground or gaps in the sward. In meadows, grasses are more abundant at the first cut, as at this time they have entered the generative phase and there is a relevant contribution of their stems to the yield.

The opposite is true for legumes and forbs, which usually contribute relevant amounts in the regrowths. Since upright/erect grasses regenerate from the stubble after harvest, they are less adapted for intensive utilisation. Turf grasses regenerate from the remaining leaf area after harvest or grazing, since the growing point remains at the bottom of the sward when defoliated. Therefore, they require/tolerate frequent harvests or grazing. Otherwise the oldest (lower) leaf decays due to unfavourable light conditions.

Table 1.1. Main differences between tussock-forming and turf-forming grass species. The given information is valid only in general and can have exceptions depending on the single species and location.

Type	**Tussock grass**	**Turf grass**
Reproduction	mainly generative	mainly vegetative
Tolerance to frequent defoliation	low	high
Tolerance to grazing	low	high
Sward density	low	high
Deterioration of forage quality with advance in phenological development	high	low
Examples	*Dactylis glomerata* (Cocksfoot), *Festuca pratensis* (Meadow fescue), *Phleum pratense* (Timothy); *Phalaris arundinacea* (Reed canary grass)	*Lolium perenne* (Perennial ryegrass), *Poa pratensis* (Smooth-stalked meadowgrass), *Festuca rubra* (Red fescue)

Another categorisation of forage grasses is based on whether a cold period (vernalisation) before the generative stage after the spring growth is needed (leaf grasses) or not (stem grasses). Examples of leaf grasses are cocksfoot (*Dactylis glomerata*), meadow fescue (*Festuca pratensis*), smooth-stalked meadow grass (*Poa pratensis*) and red fescue (*Festuca rubra*). Reed canary grass (*Phalaris arundinacea*) is a typical stem grass and timothy (*Phleum pratense*) is more like a stem grass than a leaf grass. The stem grasses are more vulnerable to frequent defoliation compared to leaf grasses.

The advantage of **legumes** in the sward is their ability to fix atmospheric nitrogen thanks to a symbiosis with bacteria (*Rhizobium* spp.) and to contribute to high leaf proportions of good quality, i.e. high protein concentration and low fibre content. They thus allow to reduce nitrogen fertilisation without decreasing production, and to increase forage quality.

Forbs can highly vary in their morphology, but they usually contain high amounts of macro nutrients, secondary metabolites (both favourable and unfavourable, depending on the species) and have favourable digestibility because of their high proportion of leaves. Forbs rich in rough stems (i.e. *Apiaceae*) are usually less favourable in terms of forage quality. It is a rule of thumb that a higher forage intake can be achieved if swards contain up to 20% of non-toxic forbs. If their proportion exceeds certain species-specific thresholds, forbs can be detrimental for the sward density, resulting in smaller yields, higher permeability to weed invasion and disadvantages with respect to forage conservation (i.e. crumble losses in case of hay making). Moreover, the most relevant poisonous species belong to this group.

Characteristics of the main grassland species

The knowledge of grassland species (both their determination and the knowledge about their ecological and agronomical traits) is the prerequisite to understand what's going on in the sward and to timely adapt the management. Otherwise no appropriate measure for assessment of the actual sward quality is possible with respect to the focussed aims, e.g. high forage quality. To this aim, we summarise some relevant characteristics of the most frequently occurring species in the temperate European grasslands in two tables. Table 1.2 provides basic information about the species morphology, while Table 1.3 focuses on the agronomical traits of the same species. Some facultative weeds (species undesirable, if occurring in high proportions) and absolute weeds (species undesirable or noxious regardless of their abundance) are included as well.

Determination of grassland species

Only a short description of the determination of grasses will be presented here. As in productive grassland the defoliation often occurs before flowering time of all species, it is particularly important to master the determination at the vegetative stage. Good keys are available in the respective national languages (some examples: English: Hubbard, 1992; Frame *et al*., 2014; German: Klapp & Opitz von Boberfeld, 2011ab, Dietl *et al*., 1998; Italian: Dietl *et al*., 2003; Swedish: Westerlind *et al*., 1997). However, the most relevant morphological traits for the determination of grasses can be used as follows:

- **First step:** Is the youngest (uppermost) leaf rolled or folded?
- **Second step:** How is the texture of the leaf blade (lamina)?
- **Third step:** How is the surface and respective bottom of each leaf formed? Is it riffled or shiny?
- **Fourth step:** How is the leaf base (auricle, ligule) formed?
- **Fifth step:** If occurring at the time of the assessment: What does the inflorescence tell you about the species?

Table 1.2. Morphology and ecological characteristics of the main grassland species. The table is a compendium of numerous sources (among them Klapp & Opitz von Boberfeld, 2011; Dietl & Jorquera 2003; Landolt *et al*., 2010) and the author's own experience.

Botanical name	Common name	Growth form: 1=tussock, 2=turf	Youngest leaf: 1=rolled, 2=folded, 3=bristle-like	Texture of upper side of leaf blade: 1=ribbed, 2=smooth, 3=tramlined	Bottomside of leaf blade: 0=not shiny, 1=shiny	Auricles	Ligule	Hairiness: 1=yes; 0=no	Inflorescens and spikelet	Vegetative reproduction	If vegetative: 1=rhizome, 2=stolon	Winter hardiness	Suitable for wet sites	Suitable for dry sites	Soil reaction (RZ)
Grasses															
Agrostis capillaris	Common bent	1	1	1	0	no	yes	0	panicle	no		+++	+	-	2
Agrostis stolonifera	Creeping bentgrass	2	1	1	0	no	yes	0	panicle	yes	2	++	+	+	4
Alopecurus pratensis	Meadow foxtail	1	1	1	0	no	yes	0	spike	yes	1	+++	++	-	3
Anthoxanthum odoratum	Sweet vernal grass	1	1	1, 2	0	yes	yes	1	panicle	no		++	+	+	2
Arrhenatherum elatius	Tall oat-grass	1	1	1	0	no	yes	1	panicle	no		+	+	+++	4
Dactylis glomerata	Cocksfoot, Orchardgrass	1	2	2	0	no	yes	0	panicle	no		+++	+	++	4
Deschampsia cespitosa	Tufted hairgrass	1	1	1	0	no	yes	0	panicle	no		+++	+	+	3
Elymus repens	Couch grass	2	1	1, 2	0	yes	yes	1	spike	yes	1	++	++	++	4
Festuca arundinacea	Tall fescue	1	1	1	1	yes	yes	0	raceme	no		++	-	+++	4
Festuca pratensis	Meadow fescue	1	1	1	1	yes	yes	0	raceme	no		+++	+	-	4
Festuca rubra	Red fescue	1	3	1	1	no	yes	0	raceme	yes	2	+++	+	++	3
Holcus lanatus	Fog grass	1	1	2	0	no	yes	1	panicle	no		+	+	+	3
Lolium perenne	Perennial ryegrass	1,2	2	1	1	yes	yes	0	panicle	no		+	+	-	4
Phleum pratense	Timothy	1	1	2	0	no	yes	0	spike	no		+++	+	-	3
Poa pratensis	Smooth-stalked meadowgrass	2	2	2, 3	1	no	no	0	panicle	yes	1	++	+	-	3
Poa trivialis	Rough-stalked meadowgrass	1,2	2	2, 3	1	no	yes	0	panicle	yes	2	++	+	+	3
Trisetum flavescens	Gold oat grass	1	1	1	0	no	yes	1	panicle	no		++	+	+	3
Legumes															
Lotus corniculatus	Birdsfoot trefoil									no		++	+	++	4
Medicago lupulina	Black medic									no		++	-	+	4
Medicago sativa	Alfalfa									no		+	-	+++	4
Onobrychis viciifolia	Sainfoin									no		-	-	+	4
Trifolium hybridum	Alsike clover									no		++	++	-	4
Trifolium pratense	Red clover									no		++	+	+	4
Trifolium repens	White clover									yes	2	++	+	+	4
Forbs															
Achillea millefolium	Yarrow									no		++	+	+	
Anthriscus sylvestris	Cow parsley									no		++	+	-	
Carum carvi	Caraway									no		++	+	-	
Cichorium intybus	Common Chickory									no			+	+	8
Cirsium spp.	Thistle									no		+	+	-	7
Daucus carota	Wild carrot									no		+	+	+	
Geranium pratense	Meadow crane's-bill									no		++	+	-	8
Heracleum sphondylium	Common hogweed									no		++	-	++	
Plantago lanceolata	Ribwort plantain									no		++			
Ranunculus acris	Meadow buttercup									no		++	++	-	
Ranunculus repens	Creeping buttercup									yes	2	++	++	--	
Rumex acetosa	Common sorrel									no		++			
Rumex crispus	Curly dock									no		++	++	--	
Rumex obtusifolius	Broad-leaved dock									no		++	+	-	
Senecio spp.	Ragwort												+	+	7
Taraxacum officinale	Dandelion									no		++	+	-	

RZ refers to the soil reaction requirement ranging from 1 (extremely acid) to RZ 5 (alkaline, high soil pH).

Table 1.3. Agronomical traits of the main grassland species. The table is a compendium of numerous sources (among them Klapp & Opitz von Boberfeld, 2011; Dietl & Jorquera 2003; Landolt *et al*., 2010) and the author's own experience.

Botanical name	Common name	Properties								Suitable for								
		Competition at establishment	Earliness at booting	Proneness to dominance under favourable conditions	Yield potential	Forage quality	Deterioration of forage quality with phenological advance	Palatability	Overall forage value (WZ)	Mowing	Grazing	Cut frequency	Growth reaction to N-input	Field drying	Barn drying (drying facility)	Silage	Temporary grassland	Threshold to weed status (yield proportion in %)
Grasses																		
Agrostis capillaris	Common bent		-	+	+	+	+	++	5	++	+	1-2	+	++	++	-	-	-
Agrostis stolonifera	Creeping bentgrass		+	++	+	+		+	5	++	-	1-2	+	+	++	+	-	-
Alopecurus pratensis	Meadow foxtail	+	++++	+++	+++	++	++	++	7	++	+	2-4	+++	+	++	+++	-	-
Anthoxanthum odoratum	Sweet vernal grass		+++	-	-	+		+	3	++		1-3	+				-	-
Arrhenatherum elatius	Tall oat-grass	++	++	++	++	+	++	++	7	++	-	1-2	++	++	++	+	-	-
Dactylis glomerata	Cocksfoot, Orchardgrass	++	++	++	+++	+	+	++	7	++	+	1-4	++	++	++	+++	++	-
Deschampsia cespitosa	Tufted hairgrass		+	++	++	-	+++	-	3	+	-	1-2	+	++			-	10
Elymus repens	Couch grass	+	++	+++	++	-	+	+	4	++	-	1-3	+++	++	++	++	-	20
Festuca arundinacea	Tall fescue	-	++	++	++	+	++	+	4	++	±	3-4	++	++	++	++	-	-
Festuca pratensis	Meadow fescue	+	+	+	+	++	-	+++	8	++	+	2-4	+++	++	++	+++	+	-
Festuca rubra	Red fescue	-	++	++	+	+	+	++	5	++	+	1-3	+	++	++	+	-	-
Holcus lanatus	Fog grass		++	-	-	-		-	4	+		1-3	+	++	++	++	-	15
Lolium perenne	Perennial ryegrass	+++	+++	+++	+++	+++	-	+++	8	++	+++	2-5	+++	+	++	+++	++	-
Phleum pratense	Timothy	+	-	+	+	++	+	++	8	++	+	1-4	+++	++	++	+++	++	-
Poa pratensis	Smooth-stalked meadowgrass	-	++	++	++	+++	-	+++	8	++	+++	3-5	++	++	++	++	+	-
Poa trivialis	Rough-stalked meadowgrass	+	++	++	-	++	+	-	4	++	-	3-5	++	++	++	+	-	15
Trisetum flavescens	Gold oat grass	+	+	++	++	++	+	++	4	++	-	1-3	+	++	++	-	-	-
Legumes																		
Lotus corniculatus	Birdsfoot trefoil	-	++	++	+	++	-	++	7	++	+	1-3	-	++	+++	+	-	-
Medicago lupulina	Black medic	-	++	+	-	++	-	++	7	++	+	1-3	-	+	++	+	-	-
Medicago sativa	Alfalfa	++	++	+++	+++	+++	-	++	8	++	-	2-5	-	-	++	+	++	-
Onobrychis viciifolia	Sainfoin	+		++	+	++	-	++	7		-		-	+	++	+	+	-
Trifolium hybridum	Alsike clover	-	+++	+	+	++	-	++	7	++	-	1-3	-	+	+++	+	+	-
Trifolium pratense	Red clover	+	++	++	++	++	-	++	7	++	+	2-5	-	++	+++	+	++	-
Trifolium repens	White clover	++	+++	+++	+	+++	-	++	8	++	+++	1-5	-	++	++	+	++	-
Forbs																		
Achillea millefolium	Yarrow			+	-	+	-	+	5	+	+	1-4	-	+	++	+	-	10
Anthriscus sylvestris	Cow parsley			+++	+	+	+	++	4	++	-	1-3	++	-	+	+	-	15
Carum carvi	Caraway			+	+	++	-	++	5	++	+	1-3	+	+	++	+	-	20
Cichorium intybus	Common Chickory			++	++	++	-	++		++		1-4			+	+	+	-
Cirsium spp.	Thistle			++	+	-	+	-	0	-	-	1-2	+				-	2
Daucus carota	Wild carrot			+	+	++	-	++	5	++	-	1-2	+	+	++	+	-	-
Geranium pratense	Meadow crane's-bill			+++	+	-	+	-	2	++	-	1-2	++	-	+	+	-	15
Heracleum sphondylium	Common hogweed			+++	+	+	+	++	5	++	-	1-3	++	-	+	+	-	10
Plantago lanceolata	Ribwort plantain			+	+	+	-	++	5	++	+	1-3	+	+	++	+	-	15
Ranunculus acris	Meadow buttercup			++	+	-	+	-	-1	++	-	1-3	+	-	+	-	-	5
Ranunculus repens	Creeping buttercup			++	+	+	+	+	2	++	+	1-3	+	-	+	-	-	10
Rumex acetosa	Common sorrel			++	+	+	+	+	3	++	-	1-3	+	+	++	+	-	15
Rumex crispus	Curly dock			+++	++	-	++	+	1	++	-	1-4	++	-	+	+	-	1
Rumex obtusifolius	Broad-leaved dock			+++	++	-	++	+	1	++	-	1-4	++	-	+	+	-	1
Senecio spp.	Ragwort			++	+	--		-	-1	+	-						-	1
Taraxacum officinale	Dandelion			++	+	++	-	++	5	++	+	2-4	++	-	+	+	-	20

Rating ranges between +++ very high or highly suitable to – very low or unsuitable. Overall forage value (WZ) ranges from 8 (maximum value) to 0 (no value) and -1 (poisonous species).

Sward assessment

The regular and periodic assessment of the botanical composition of the plant stand represents a valuable management tool in grassland farming, as this allows to recognise and interpret ongoing trends in the vegetation and react with proper adaptation of management.

In order to get reliable information about the sward, a few rules must be followed:

- a surveyed area of about 50 m² is usually sufficient in managed grassland
- if the surveyed grassland is not homogeneous, the choice of a representative area may be tricky. In this case more than one area should be assessed

- the yield proportion of species or species groups usually changes over the season (i.e. in meadows grasses are most abundant at the first cut, the opposite is true for legumes and forbs); if assessments over years are to be compared, the assessment should be temporally and spatially homogenous.

The abundance of species can be described using different parameters (plant density, frequency, cover), but for agronomic aims the yield proportion of species has great relevance, as it describes the contribution of each species to the yield. The yield proportion is the relative proportion (in percent of weight) of the harvestable above-ground dry matter biomass of a certain species or a species group related to the total dry matter yield. For the assessment, several methods differing in accuracy, time consumption and necessary tools to perform the assessment are available, but for practical aims also the visual estimation results in acceptable accuracy, as long as the same observer with a minimum training repeats the assessments over time.

In order to assess grassland biodiversity, a complete species list is necessary, implying that all occurring species are determined and assessed. For practical aims of grassland management, however, a simplified system based on the yield proportion of species groups (grasses, legumes, forbs) can be used. To this aim, graminoids (sedges, rushes) are included into the grass group. Depending on the yield proportion of these groups, the plant stand can be assigned to one of four groups (Figure 1.9): rich in grasses, balanced, rich in forbs or rich in legumes. Already with this simple tool, relevant information can be gained about grassland management (Table 1.4).

Figure 1.9. Key to determine the sward type based on the yield proportion of grasses, legumes and forbs. Source: webGRAS (https://webgras.civis.bz.it/#/start), modified.

Table 1.4. Hints about grassland management that can be inferred based on a simplified sward assessment of mixed swards in permanent grassland.

Plant stand type	Rich in grasses	Balanced	Rich in forbs	Rich in legumes
Yield potential	++	+	+	-
Crude protein potential	-	+	+	++
Forage quality stability along phenological development at the first cut	-	+	+	++
Easiness of silage conservation	++	+	-	-
Drying speed	++	+	- [a]	+
Risk of crumbling losses	-	-	+	+
Risk of contamination with soil	-	-	+	+

++ high, + medium, - low;

[a] particularly in case of forbs with rough stems

Always bear in mind that the actual grassland sward is a result of complex interactions with respect to the soil, management, climate and care. In the case famers find out that the present grassland conditions do not meet the expectations, several options are possible. The first one is to reconsider the management. The species occurring in the sward can be used as indicators of what is going on. Management intensity, including defoliation frequency and fertilisation should be verified and, if appropriate, changed or adapted. Sward care should be applied to promote an increase of the desired forage species. The introduction of valuable forage species or the increase of their yield proportion can be sought by means of a periodic oversowing (no need for complete sward renewal) or, in case of the absence of a critical mass of valuable forage species, by means of resowing, which require good knowledge.

1.4 Weed management

Alain Peeters (RHEA Research Centre) and Nilla Nilsdotter-Linde (Swedish University of Agricultural Sciences)

As described in section 1.1, permanent grassland vegetation includes often grass, legume and other species. This last category comprises non-leguminous dicotyledons and grass-like plants. Even temporary grassland can exhibit a certain plant diversity. Grasses and legumes are usually dominant, but several spontaneous species may appear in the sown sward.

Non-leguminous dicotyledons have been for long considered as **weeds** that should be destroyed by herbicides or other means. Many are currently recognised as forage plants that can bring nutrients and secondary compounds that are beneficial to livestock. They may also increase forage intake by grazing animals. They can be called ‘herbs’.

A **weed** can be simply defined as a plant that appears where it is not supposed to be! Real weeds are restricted to a few species. There are two categories: annual and perennial species.

Annual species include notably chickweed (*Stellaria media*), fat hen (*Chenopodium* spp.), common knotgrass and redshank (*Polygonum aviculare* and *Persicaria maculosa*), annual nettle (*Urtica urens*), and chamomiles (*Matricaria* spp.). They may compete too much with forage species just after sowing of a new sward. This could lead to insufficient forage plant establishment. Even if forage plants are well established, the presence of some annual weeds, especially fat hen and chamomile, in the young sward can decrease forage quality of the next harvest.

There are several techniques that reduce annual weed invasion risk. The following practices are the most important:

- careful sowing bed preparation
- choice of an adequate seed mixture
- choice of a favourable sowing period
- topping of the young sward before the first harvest

When there is a risk of weed invasion in the plot chosen for establishing a grass sward, false or stale seed bed can be prepared some weeks before grassland sowing. It could be done in summer after the cereal harvest for instance or in spring (see comment on sowing period choice below). The soil is finely prepared as for a true grassland sowing. This stimulates weeds germination. Once weeds have massively germinated and reached the cotyledon or the first leaf stage, they are mechanically destroyed by the superficial passage of a harrow or other means. This operation can be repeated once or twice if necessary. Then forage seeds are sown in a clean seed bed.

Forage plant seeds are very small. They require a very well prepared and fine seed bed for ensuring a close contact between soil and seed. After sowing, rolling is often advised for further improving soil-seed contact. These measures ensure a fast and regular germination which increases the chances of good establishment and weed control.

The outcome of competition between young forage plants and weeds very much depends on the germination and establishment speed of forage grasses and legumes. There are significant differences in germination and tillering speed between grasses. Italian ryegrass germinates and establishes very fast, perennial grass is fast, cocksfoot and tall fescue are slow, timothy is slow and a weak competitor. Pure timothy sowings are unsurprisingly often invaded by weeds. Large differences are also noted in legumes. The annual crimson clover germinates and establishes very fast, red clover is fast, lucerne is slow, white clover is slow and requires a long establishment phase during which its competitive ability is low. An Italian ryegrass/red clover mixture for instance is thus covering soil surface very quickly and is able to efficiently control weeds.

In contrast, sowing density is not so important for controlling weeds. Above the recommended sowing density threshold, for instance 30 kg of perennial ryegrass seed per ha, no significant effect of increased density on weed control is noted.

The choice of the sowing period is extremely important. Autumn sowing (second half of August – beginning of September) is safer than spring sowing (April – May) in North West Europe. Fat hens for instance mainly establish in late spring sowing. This tall and branched plant is extremely competitive, and its very fibrous stems are little digestible. In autumn, sowing should not be delayed too much otherwise germination could be too slow and young plants can even be destroyed by winter frost. Legumes are more demanding than grasses in terms of soil temperature. They should be sown before the 15th of September in North-West Europe and before 1st August in the Nordic countries. This date varies according to location and weather conditions.

Sowing date depends also very much on favourable soil humidity conditions. Sowing in dry conditions increases risk of fat hen, common knotgrass and redshank invasion because these plants can germinate in conditions that are too dry for forage grass and legume seeds.

Even when the preceding measures are adopted, young swards can still sometimes contain too much weeds. The abundance of these weeds could be judged as too high for a good quality harvest. Topping is then an option for reducing their importance. Annual weeds usually establish faster and grow faster than perennial forage plants. When weeds start their reproductive period and produce stems, these stems are often significantly taller than the average height of forage plants. The sward can then be cut below the average height of forage plant canopy. When conditions are favourable, most annual weeds are then destroyed or at least their proportion in the sward is very much reduced. New weed seeds can sometimes germinate later, but the risk is much less when there is a dense sward of the desirable species.

Perennial species weeds include docks (*Rumex obtusifolius* and *R. crispus*), creeping thistle (*Cirsium arvense*), stinging nettle (*Urtica dioica*), ragwort (*Senecio jacobea*) and couch grass (*Elytrigia repens*).

Moreover, creeping buttercup (*Ranunculus repens*), when too abundant in a sward, can also reduce its yield and forage quality. This situation is encountered on poorly drained and wet soils where inadequate management provoked grass progressive disappearance. Management should thus be improved in priority and the opportunity to improve drainage could be analysed.

Perennial weeds can sometimes create problems in both permanent and temporary grasslands. Prevention measures are priority. Since most species except couch grass can produce a lot of viable seeds per plant each year, management should prevent seed production and spreading. This can be done for instance by alternating grazing and cutting, by cutting refuses in grazed swards, and by adopting a fast cutting regime, for instance four cuts per year in exclusively cut grasslands.

Animals can be used as ‘collaborators’ of the grazing system manager for controlling weeds. Examples, which are only valid in particular European areas, are given hereunder. In grazed permanent grasslands, sheep and particularly goats can help controlling docks. Donkeys can be used for controlling thistle. They are indeed able to browse thistle stems and flowers if they don’t have choice.

In arable land, when temporary grasslands are part of an annual crop rotation, the period between crop harvest and grassland sowing can be used for controlling docks, thistle and couch grass by mechanical means. Techniques differ according to species. Dock roots should never be cut in small pieces by the superficial action of a rotary harrow or rotavator because each fragment could produce a new plant. This type of action would actually multiply dock plants, and even sometimes in a tremendous way. The ideal technique consists in using a harrow equipped with wide wing coulters that cut roots at minimum 7 cm deep. The deep tap root of dock can indeed not produce new stems when cut at this depth. The upper part of the roots could sprout again. They should be dragged away on the soil surface by tine harrow and dried out. In case of strong invasion, these roots can even be collected on the surface. Couch grass rhizomes can also be dragged away on the soil surface by tine harrow and dried out. Thistle cannot be controlled in a similar manner because its rhizome can be as deep as two meters. There is however a very efficient method for eliminating them totally. Lucerne/grass mixture cut four times a year during two to three years totally eliminates creeping thistle. This weed species does not tolerate frequent cuts, its regrowth after a cut is slow and after some cuts it is totally dominated by the fast-growing forage mixture. This technique is also efficient on couch grass.

Herbicide use should be the last option if a farmer decides using these products. Herbicide can be efficient on dock, stinging nettle, ragwort and couch. They are frequently not efficient on thistle because after foliage destruction, the strong rhizomes produce new stems again the next year.

More information: Meadow mania, Information on the common grassland weeds: www.meadowmania.co.uk/news/information-on-the-common-grassland-weeds/ (technical and scientific synthesis, and scientific papers are available on this site)

2. Grazing management

Fergus Bogue, Michael O'Donovan (Teagasc), Leanne Aantjes, Agnes van den Pol-van Dasselaar (Aeres)

When it comes to maximising the benefits of grazing, there is a lot to learn from Irish grazing management. Therefore, this chapter is in majority based on guidelines and insights from Ireland, where the majority of the herds are spring-calving. Even though grass based systems are in general seen as low cost systems, there is a tendency in Europe that ruminant production systems are intensifying, leading to more concentrates and maize in the rations of the cows, less grass in the ration and less grazing. Furthermore, the assumed economic benefits of grass based systems are not achievable in practice in some European areas due to farm and pedoclimatic conditions or are perceived as impossible by farmers. They choose to be less grass based and transform part of their grasslands to more profitable systems. However, the principles presented in this chapter are useful knowledge for all farmers that practice grazing, either full grazing or restricted grazing with supplementary feeding.

Chapters 2.1, 2.3, 2.4 and 2.5 are based on Grazing Guide 2 – Joint publication between Teagasc and Irish Farmers Journal (2016), 90 pages, www.farmersjournal.ie

2.1 Grass supply

Fergus Bogue, Michael O'Donovan (Teagasc), Leanne Aantjes, Agnes van den Pol-van Dasselaar (Aeres)

<u>What's in grass?</u>

The protein content of purchased rations and, increasingly so, the UFL (energy value) of purchased rations can be rolled off the tongue of any farmer in the country. But knowledge about the nutritional attributes of grazed grass, which makes up 60-80% of the total dry matter intake of most ruminants, is less well known.

Grass can be divided into its water and dry matter content. As you can see below from Figure 2.1, 100 kg of grass will contain approximately 83 kg of water. But it's the dry matter that contains the key nutrients that the animal needs. The dry matter can be divided into cell wall and cell contents. The cell wall of grass is the fibre content, while the cell contents include sugar, protein, fats, minerals and other compounds.

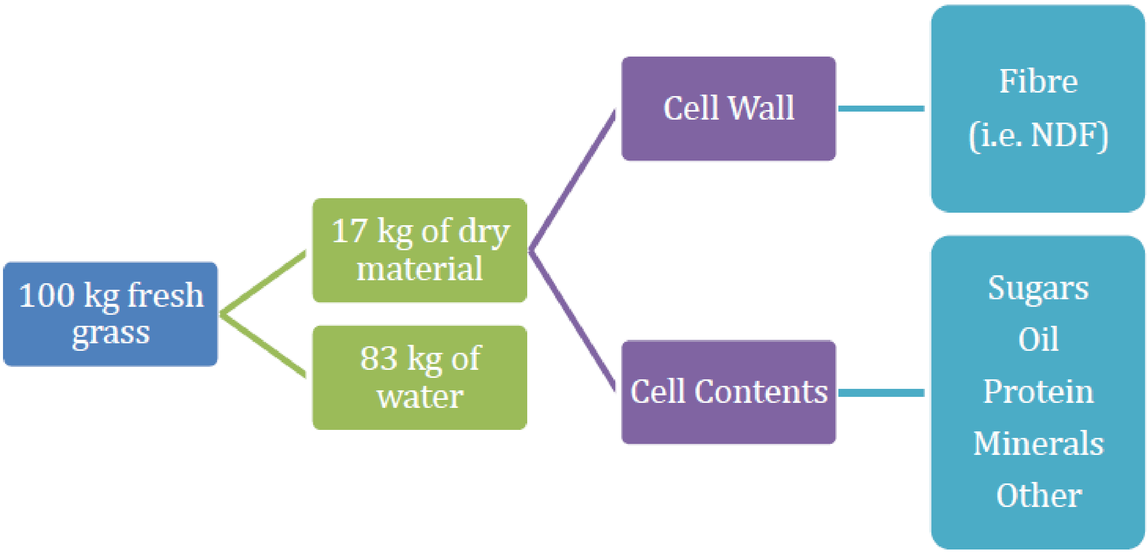


Figure 2.1. What's in Grass?

<u>Energy</u>

The energy in grass comes primarily from the sugar & fibre content, with some energy from oil & protein. The higher the proportion of leaf in grass (ideally over 80%), the higher the energy content coming from sugars and digestible fibre. Fibre is a key supplier of the energy in grass but it needs to be quality fibre. As the proportion of stem in the grass plant increases, the digestibility of the fibre decreases and consequently the energy content decreases. Therefore, grazing leafy grass is ideal for maximising performance.

The energy content of grazed grass varies from 1.05 UFL / kg DM for leafy fresh spring grass to 0.85 UFL / kg DM for very stemmy grass in the autumn. This compares well to other feeds (Figure 2.2). Grass energy content is controlled by maintaining swards with high quality grass content but equally important is good grassland management – grazing out of paddocks in springtime, maintaining a 21 days rotation through the main grazing season, avoiding grazing heavy covers of grass and grazing to 4 cm.

The energy demands of the dairy cow can be met by a grass only diet throughout the main grazing season, with some supplementation needed at the shoulders of the year when grass supply is limiting. Likewise the energy demands of the suckler cow, calves, yearlings and finishing steers & heifers can be met by a grass only diet. Dairy production can increase by supplementation, but these come with a cost.

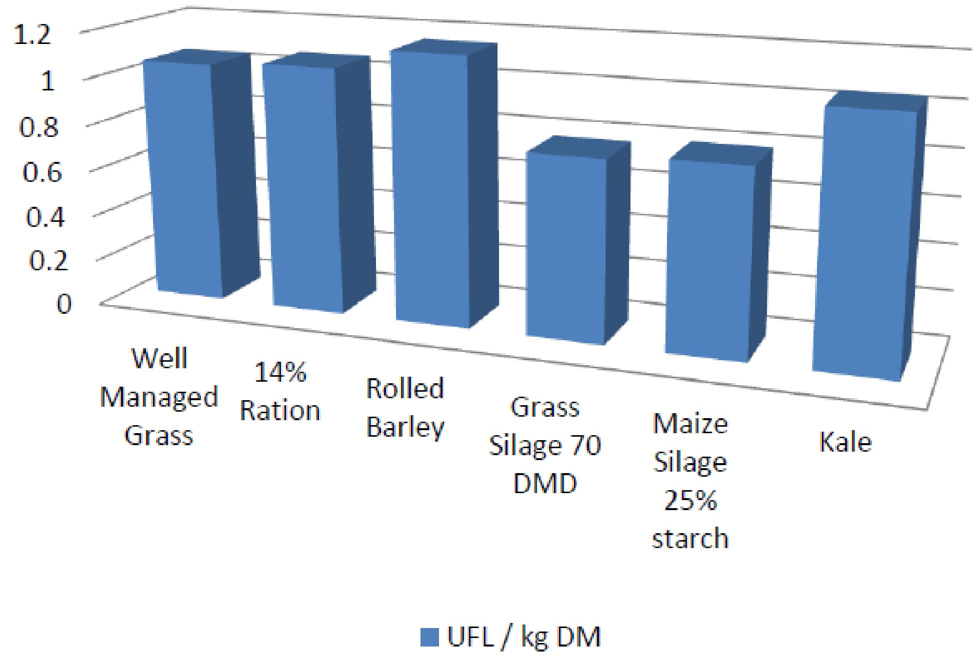


Figure 2.2. The energy content of various feeds.

Protein

The protein in any feed can be divided into the quantity and quality of the protein. The quantity of protein in grass varies typically from 16-28%, depending on the sward type, growth stage, fertiliser regime and time of the year. Occasionally, protein levels in grass dip as low as 11-12%. This can happen during a period of stress on the grass plant, e.g. a drought. Quality of protein is defined by systems that account for the quantity of protein that can be utilised by the animal, i.e. not all protein in a feedstuff is utilisable by the animal.

So how much protein does the animal need? Protein is a key nutrient for appetite, milk production, reproduction and growth. Young, growing cattle and lactating cows need most protein. Young stock need 13-15% CP (crude protein) in the diet, lactating cows with full grazing 14-17%, depending on yield and finishing cattle need 11-12% CP. Based on this information, it’s clear that the quantity of protein in grass is in excess of requirements in the case of full grazing. In fact, there is an energy cost to the animal excreting the excess protein in grass. Therefore, avoid feeding supplementary protein on grass. There is a cost in buying it, a cost in excreting the excess protein and an environmental cost.

Protein quality tends not to be an issue for young stock, suckler cows or finishing cattle on grass. But for freshly calved cows in springtime, there is a need for some quality protein from ration for the first 6 weeks of lactation. And while autumn grass has adequate protein for late lactation spring calving cows, freshly calved autumn calving cows need some quality protein in the ration to meet their requirements.

Fibre

The rumen is the engine house of the ruminant animal, so maintaining a healthy rumen is key to good performance. Ruminants are unique in their ability to digest fibre from grass and other forages. And fibre is important in maintaining a healthy rumen. Cows have a specific requirement for fibre. When this requirement is not met, rumen pH becomes unstable and animal performance suffers.

Too little fibre is a problem, but likewise too much fibre is a problem. Too much fibre reduces dry matter intake, reduces energy intake, reduces body condition gain and lead to production losses. The fibre content of grass is defined by the neutral detergent fibre content (NDF, %). The NDF content of grazed grass varies from 35% for leafy fresh spring grass to 50% for stemmy grass. Dairy cows need a minimum of 30% fibre (NDF) to maintain a healthy rumen. Beef cattle can thrive with much lower levels of fibre in the diet. So mostly there is more than adequate fibre in grazed grass. Rumen pH (level of acidity) tends to be lower in grazing diets but research work from Northern Ireland, New Zealand and Australia indicate that feeding additional roughage has no impact on animal performance.

Minerals

The mineral content of grazed grass can be divided into major elements (including calcium, phosphorus, magnesium, sodium and sulphur) and trace elements (including copper, selenium, iodine, cobalt, manganese and zinc). As is evident from Figure 2.3, major elements tend to be well supplied in grazed grass but deficiencies of major elements do occur, e.g. magnesium during the tetany period or phosphorus on deficient soils.

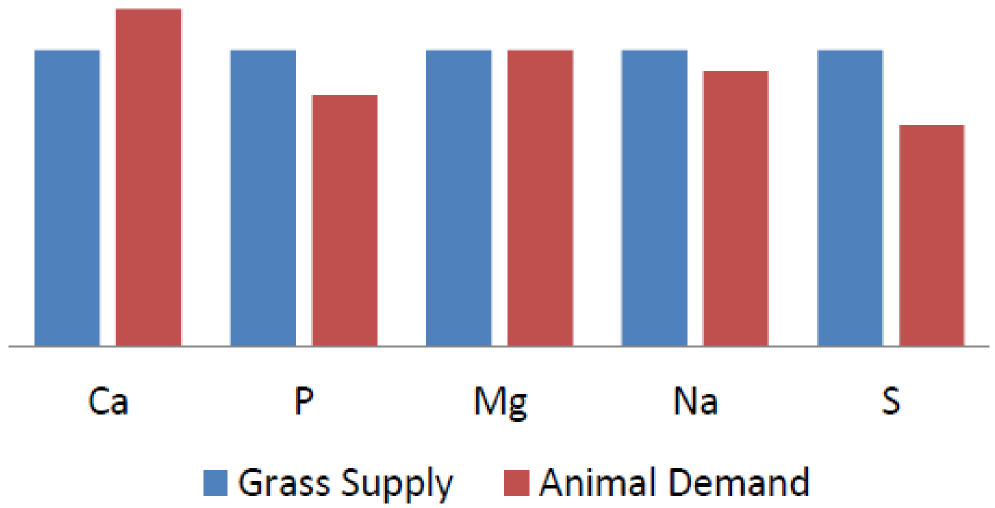


Figure 2.3. Grass supply relative to dairy cow demand for major elements.

Trace elements levels in grass are low (Figure 2.4) and consequently need to be supplemented at key periods during the year including pre-calving, post calving, during the tetany period and during the breeding season.

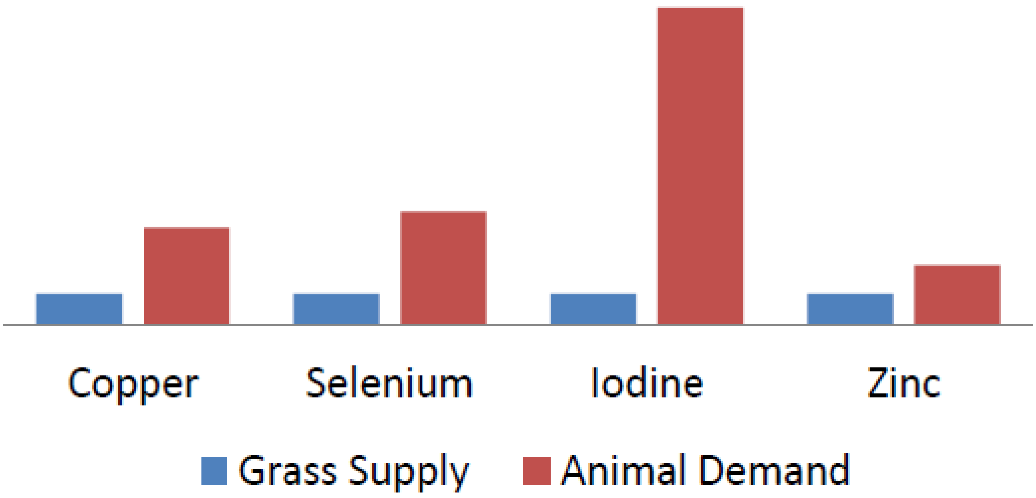


Figure 2.4. Grass supply relative to dairy cow demand for trace elements.

Take the guess work out of mineral supplementation and get your grass analysed every 3-4 years. This will establish the mineral status of the grass and the presence of any antagonists such as molybdenum and iron. While grass is deficient in trace elements, over-supplementing with trace elements can cause more problems than it will solve, i.e. toxicity.

Cost

Grazed grass remains our cheapest feedstuff to produce. Examples from Ireland show that grass is at €80 / 1,000 units of energy (Figure 2.5). It is 2.5 times cheaper than grass silage and 3.5 times cheaper than a ration at €275 / tonne.

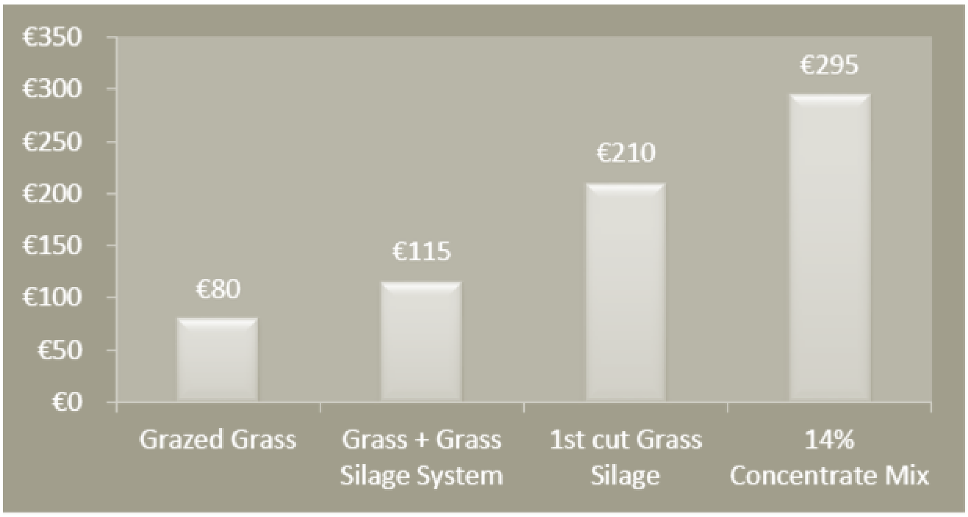


Figure 2.5. The cost of grazed grass relative to grass silage and concentrate feeds (€/1,000 UFL) in Ireland.

2.2 Main parasitic diseases encountered on the pasture

Patrik Gauder (AWE), Daniel Jacquet (AWE), Leanne Aantjes (Aeres)

Grazing cattle are subject to various parasitic diseases. Most often it is possible to work on the grassland management to reduce infestations.

<u>Distomatosis</u>

It is a subclinical disease that affects all categories of animals and that can have serious economic consequences. It is caused by the liver fluke (*Fasciola hepatica*). The parasite is ingested by the animal and goes in the liver where it causes lesions. The symptoms appear gradually over several years. They result in a loss of weight, a decrease of milk production and fertility.

Snails, and other amphibious mollusk are the intermediate host of the liver fluke larvae. In order to reduce the risk of infestation, these intermediates must be reduced on the sward. For this purpose, ensuring a good soil drainage of the meadows is important. Moreover, applying calcium cyanamide may be useful.

<u>Bronchial and gastrointestinal worms</u>

Lung and gastrointestinal worms mainly affect young animals. The lungworms (*Dictylocaulus viviparus*) cause bronchial lesions. Symptoms are cough and breathing difficulties. The gastrointestinal worms of ruminants are located in the abomasum (*Haemonchus contortus, Oestertagia*) and in the small intestine (*Cooperia, Trichostrongylus Axei, Nematodirus, Strongilidés, Monieza, Oesophagostomum*). They cause inflammation of the mucous membranes, diminish the absorption of nutrients, cause diarrhea and a decrease in performance.

When letting the cattle on the meadow, putting a bolus in the rumen or ivermectin treatments are often used to prevent against these parasites.

<u>Coccidiosis</u>

Coccidiosis is caused by a protozoan (*Eimeria bovis, zurnii*). This parasitic contamination happens mostly in summer and especially affects young animals that get infested by ingesting the parasite eggs. The presence of wet areas in the meadow favours the development of this parasite. Nevertheless, the pasture is not the only place the cattle get infested. It can also happen in the stables. In the animal, the parasite localizes in the colon, the cecum and the rumen where it causes destructive lesions of mucous membranes. The animals suffer from haemorrhagic diarrhea, weight loss and anemia.

To prevent it, the formation of wet spots on the meadow should be avoided. If possible, the water points are moved to disrupt the development of this parasite in these areas. Most used treatments are injections of sulfonamides or ingestion of amprolium through food complementation.

Other pathologies encountered by young calves

Young calves can suffer from enterotoxaemia. It is caused by the absorption of large volumes of toxins produced by *Clostridum perfringens* from the intestines. There are not much symptoms and death can happen within a few days. Unfortunately, there is no effective treatment against it. Medical prophylaxis (vaccination) and food prophylaxis remain the only cures. Regarding the food, it is important to allow enough fibrous food in the ration of the suckler cows and avoid any abrupt dietary changes. Complementation to keep an equilibrated ration may also help.

Calves can also have diarrhea as soon as they are put on the meadow. This translates by white faeces, symptoms of poor milk digestion. It happens when cows consume young grass with a low dry matter content and without structure. Their milk then contains proportionally too much long chain fatty acids causing a disruption of digestion in the calf.

The calf diarrhea can also result in black faeces when the cows consume a very high quality grass and produce a milk rich in fat and protein that will cause indigestion by the calf.

2.3 Main grazing parameters

Fergus Bogue, Michael O'Donovan (Teagasc), Leanne Aantjes, Agnes van den Pol-van Dasselaar (Aeres)

Grass height and stocking rate influence grass intake and livestock production. To quantify the effect of grass height and stocking rate, a few parameters need to be known.

LU/ha

LU/ha, also known as stocking rate, is the total of all livestock units at grass divided by the measured area in hectares. Each livestock type has its own livestock units:

- Dairy milking cows, suckler cows, stock bulls, dry cows: 1.0
- 0-6 months old 0.1
- 6-12 months old 0.3
- 1 -2 years old 0.7
- >2 years old 1.0
- Lactating ewes 0.25
- Dry ewes/hoggets 0.15
- Lambs 0.0

Cover/LU

Cover/LU is Average Farm Cover divided by the stocking rate on the farm. Cover/LU is used to compare farms with varying stocking rates. Sometimes this is referred as Cover/Cow, where a cow is one livestock unit. In Ireland, this parameter is primarily used in the summer between April and August.

Average Farm Cover

Average Farm Cover (AFC) is the average amount of grass on each hectare of the farm and is expressed in kilograms of dry matter per hectare (kg DM/ha). To calculate the average farm cover, multiply the paddock area by the cover in each paddock, for all paddocks measured during a walk, and then divide by the total ha of all paddocks measured.

Average farm cover is an important parameter in the spring and autumn. Typically, AFC is high in early spring and reduces as you end the first rotation in April. Between April and August, AFC needs to be maintained. From late August to September, target AFC is increased in order that this extra grass can be grazed in October and November when demand is higher than growth.

Rotation length

The rotation length is the number of days it takes the herd to rotationally graze the whole farm. Rotation length can be calculated by dividing the total area available for grazing by the number of hectares grazed per day.

Why Measure Grass?

The potential to achieve high levels of productivity from grazed grass gives farmers a major competitive advantage over global counterparts. Existing research clearly shows that farms that grow more grass have lower costs and higher profits. On average, the cost of producing 1 kg of live weight gain or 1 kg of milk solids from grazed grass is 80% to 85% less when compared with an intensive concentrate-based system (grassland database).

Decision support tools like PastureBase Ireland aim to help farmers ensure that they are exploiting the full potential of grazed grass on their farm, irrespective of production system or land type. Land type or location is often seen as a barrier to adopting good grassland management practices. While Irish farmers use some purchased feed, the majority of weight gain or milk is produced from mainly grazed grass.

There are still a number of simple steps that farmers can take to improve grass growth, grass quality and grass utilisation. Getting livestock out to grass early and ensuring an adequate supply of good-quality leafy grass is available throughout the grazing season is key to obtaining high levels of animal performance. Measuring grass is important to achieve this. The main benefits from measuring grass are:

1. Maximise the proportion of grazed grass in the diet.
2. Maximise pasture re-growth rates.
3. Improve pasture quality, feed more grass, and at a higher quality.
4. Graze more grass in the spring and autumn, shorten the winter period.
5. Achieve target average farm covers at key times during the year.

Table 2.1. Guidelines for cover/LU, AFC and rotation length in Ireland.

Guidelines for Cover/LU, AFC and Rotation Length

Date	Cover/LU Kg DM	Average Farm Cover (AFC) Kg DM/Ha	Rotation Length Days
STOCKING RATE OF 2.5 LU/HA			
1st February	360	900	100
1st March	280	700	50
4th April	200	500	18-26
May, June, July	170	425	18-24
Mid - August	200	500	25
1st September	300	750	30
Mid-September	400-450	1,000-1,100	35
1st October	400	1,000	40
1st November	60% of your grazing platform should be closed for Spring at this stage		
Fully Housed		550-600	
STOCKING RATE OF 3.0 LU/HA			
1st February	330	1000	100
1st March	250	750	50
4th April	185	550	18-26
May, June, July	170	510	18-24
Mid - August	250	750	25
1st September	330	990	30
Mid-September	370	1100	35
1st October	380	1150	40
1st November	65% of your grazing platform should be closed for Spring at this stage		
Fully Housed		600-650	
STOCKING RATE OF 3.5 LU/HA			
1st February	285	1000	100
1st March	230	800	50
4th April	185	650	18-26
May, June, July	170	600	18-24
Mid - August	220	770	25
1st September	280	980	30
Mid-September	340	1200	35
1st October	335	1175	40
1st November	70% of your grazing platform should be closed for Spring at this stage		
Fully Housed		700-750	

How you can grow more grass

Grazed grass is, and will continue to be, the cheapest animal feed for meat and milk production. Your land's ability to produce excellent quality grass is your primary competitive advantage over other dairy farmers. To optimise profitability, producers must maximise the proportion of grazed grass in animal's diet.

What are the key performance indicators in relation to grassland management?

- A long grazing season will maximise your profitability and competitiveness. Extend the grazing season in early spring and late autumn. Grass budgeting is an essential tool in achieving a long grazing season. Paddocks should be grazed to low post grazing heights (e.g. 3.5 cm) in early spring to condition swards for subsequent grazing rotations. On/off grazing is a strategy to increase the proportion of grazed grass in the animal's diet during periods of wet weather.

- In Ireland, it is shown that increasing the proportion of grazed grass in the diet of a dairy cow by 10% reduces costs of production by 2.5 cent/litre (2011); every extra tonne of grass DM is worth in the €173/ha to a dairy farm and €105/ha on a drystock farm (2015); increasing the grazing length by 30 days will reduce costs of production by 1 cent/litre (2015). To achieve this, ensure your cows' calving pattern is matched to the start of the grass growing season. Begin calving at the onset of grass growth. Typically this should result in most calves being born between 10 February and 1 March (six weeks before growth meets demand). Use a decision support tool like the spring rotation planner on PastureBase Ireland and stick to daily area allocations as planned, graze 30% in February, 66% by 17 March and target 100% grazed by 6 April (adjust these dates for later turnout regions).
- Match your stocking rate to the growth potential of your swards.
- Ensure perennial ryegrass dominates all swards.
- Target farm DM production of 15/16t DM/ha.
- Stock the farm to its grass growth capability. e.g. 5t grass dry matter consumed per cow, grass yield 14t/ha = 2.8 cows/ha.
- Maximise the productivity of your swards through improving soil fertility
  - Soil sample one third of the farm each year. If there has been no sampling for many years consider getting the whole farm sampled.
  - Apply P, K and lime as recommended.
- Maximise the productivity of your swards through timely reseeding
  - Reseed in spring if possible.
  - Target a 60-day turnaround time from seeding to first grazing.
  - Ensure that recommended list varieties are used.
  - Use a post-emergence spray at the two-leaf regrowth stage.
  - Graze the sward for the first time at 600-700 kg DM/ha.
- Grassland Management
  - Make use of farm grass cover measurement and grass budgeting
  - Feed concentrates/high quality silage when short of grass.
- Ensure that farm infrastructure is sufficient to fully utilise the grass grown

Key performance indicators

You cannot manage something you do not measure! You must be able to estimate grass covers in each individual paddock on the farm and use this information to achieve both short daily and medium term (weekly and monthly) targets that are critical to the success of the system. Such skills can be learned from advisers, through farm discussion groups and through practice and self-training.

2.4 Management according to the season

Fergus Bogue, Michael O'Donovan (Teagasc), Leanne Aantjes, Agnes van den Pol-van Dasselaar (Aeres)

2.4.1 Spring

To capitalise on the benefits of grazed grass, dairy cows should be turned out to grass directly after calving, ground conditions permitting. The main objectives of spring grazing management are:

1. To increase the proportion of grazed grass in the diet of the dairy cow
2. To condition swards for subsequent grazing rotations.

Farm cover at turnout should be approximately 800-900kg DM/ha, depending on mean calving date – an earlier calving date equates to higher animal demand and the need for a higher opening cover. Aim to offer 1.0–1.2 tonne grass DM/cow from turnout until the end of the first rotation – this is achievable on farms where animals are turned out early. Grazed grass and concentrate can be the sole feeds with such a system. This allows grass silage to be completely removed from the diet post-calving.

Grass at a reasonable level of utilisation (80%) costs about 7 c/kg utilisable dry matter (DM) compared with first and second cut grass silage at 15 c/kg and 18 c/kg utilisable DM, respectively.

Grazed grass is the highest quality feed on the farm in spring, better than silage and equivalent to concentrates. Based on these figures, it is important to increase the grass proportion in the diet of grazing animals.

Spring is the key period to target for several reasons:

- More expensive feeds such as grass silage and concentrate can be replaced by grazed grass.
- Early spring grazing increases grass quality in the second, third and subsequent grazing rotations.
- Grazing more grass in spring will increase the total quantity of grass grown on the farm on an annual basis

During the early grazing season (February or March), a balance must be found between feeding the animal adequately, to maintain high animal performance, and conditioning the sward for the late spring/summer grazing season. In the first rotation, the key is to graze paddocks out to 3.5 to 4cm and set up paddocks for following rotations. By doing this, grass digestibility can be increased by 4-6 units in May and June.

The target is to achieve a 280-300 day grazing season. Across Ireland, the average grazing season length of Pasture Base Ireland farmers is 240 days.

Animal performance increases, of both finishing and store cattle as well as dairy cows, from early turnout are substantial.

Obstacles

One of the main obstacles to achieving more days at grass in early spring, is poor soil conditions. If animals stay in the paddock, treading damage on soils can result in reduced growth rates during subsequent grazing rotations. Even on dry soil paddocks which are severely damaged by poaching, grass supply can be reduced by 30% at the next grazing. It takes even longer for heavy soil paddocks to recover; grass growth can be reduced until the following autumn.

Allowing animals access to pasture for approximately 6 hours per day; 3 hours in the morning and 3 hours in the evening (on/off grazing) has been shown to maintain high levels of performance when compared with grass silage based diets and may be a strategy that can be implemented to extend the grazing season length. Animals can adjust their grazing behaviour to ensure that they achieve almost the same intake as they would if grazing on a fulltime basis. Once there is sufficient grass on the farm it is important not to offer the animals grass silage when they return indoors as this will decrease their appetite and reduce their grazing efficiency and compromise grass utilisation.

Do’s

- Maximise early spring grazing in the diet of freshly calved dairy and suckler cows or priority cattle e.g. replacement heifers
- Graze paddocks to 3.5cm in the first rotation
- Implement on/off grazing or remove stock from grass to prevent damage
- Achieve spring rotation planner targets e.g. 30% by 1st March, 60% by 17th March, 100% by April 4th.

Getting the turnout date right

The aim in spring is to increase the proportion of grass in the diet of the grazing animal while at the same time budgeting so that there is enough grass until the start of the second grazing rotation in early to mid-April. Spring grazing should start in February and continue until early to mid-April. This varies from farm to farm but the most important aspect of grazing management is to make good use of spring grass, it is also worth noting that the end of the first rotation can vary from year to year and is dependent on grass growth.

Get Priority Stock Out

All animals in the herd do not have to be turned out at the same time. Groups of animals should be prioritised for early turnout, i.e. those that will benefit most from high quality spring grass e.g. lactating cows, replacement heifers or steers.

Magic Day

This is the day your farm is growing as much grass as you need (i.e. grass growth = herd demand). This is dependent on the farm stocking rate and the level of supplement used, for some farmers it will be the end of March, for others it will be the middle of April. You will only be able to establish this date after a number of years of continuous grass measurement.

First Rotation

The first grazing rotation should be 40 to 50 days and finish on magic day e.g. 10th April. This can be extended to 20 April in later growing years or poorer grass growing areas.

Area to graze first

Graze 30% to 40% of the grazing paddocks first to ensure there is enough time to allow re-growths accumulate for the start of the second rotation. Silage ground should be grazed early in the first rotation — this will increase the available grazing area. Also, if grass growth is slow silage paddocks can be regrazed for a second time at the start of the second grazing rotation. This will give the rest of the grazing paddocks a few extra days to grow more grass.

Strip grazing

During the first grazing rotation fresh grass should be allocated daily. For milking cows, fresh grass should be offered after every milking. This will help increase grass utilisation.

Animals should be ‘back fenced’ – that is when they are given fresh grass they should not be given access to the area previously grazed. This will reduce poaching damage but it will also allow the grazed areas to start re-growing, thus ensuring grass for the second rotation.

Post-grazing

Post-grazing heights of 3.5cm to 4cm should be targeted during the first grazing rotation. Below 3.5cm will reduce subsequent grass growth while above 4cm will waste feed and reduce utilisation. It will also reduce grass quality in subsequent rotations.

Late turnout and high grass covers make it difficult to achieve target post-grazing heights. This will often lead to poor grass utilisation and subsequent poor pasture quality in subsequent grazing rotations.

Applying slurry in spring

Slurry, as a valuable source of N, P and K, should be applied on the fields/paddocks that need it most and at the time of year that will give you the best response.

All of the P and K in slurry is available to be utilised and fields that are low in both of these nutrients need to be targeted to receive slurry. On a lot of farms, this will be the silage fields as this is where the feed that eventually produces the slurry comes from in the first place.

The time of year that slurry is spread does not affect the availability or utilisation of P and K. This is not the case with N.

Spreading nitrogen fertilizer

Nitrogen fertilizer can provide a boost to spring grass growth, allowing for a greater proportion of the grazing animals diet to be made up of grass. It can also allow a greater number of animals to be turned out to grass in early spring. Soil temperatures need to be at least 5 °C before there is an adequate response to N and the date at which this occurs can differ from year to year. In general, spreading nitrogen on the farm, brings forward the farms grass growth rate by three weeks.

In good growing conditions, 1kg of N has the ability to grow 10 to 15kg of grass DM during February, while in other years there can be little or no grass growth response to the N due to prolonged cold weather into March. Urea is cheaper per kg N than CAN and should be used in spring wherever possible to reduce costs.

Spring rotation planner

The spring rotation planner is a tool that divides the area of your farm into weekly portions and takes the guesswork out of planning the first grazing rotation.

The spring rotation planner will not tell you if you are feeding animals enough grass — you will have to gauge that by walking through your paddocks or fields and assessing either visually or by plate meter measuring if you have enough grass. The spring rotation planner is a simple and effective tool that ensures:

- Sufficient grass is grazed early enough to allow time for re-growth for the second rotation.
- Grass does not run out before the start of the second rotation. A wedge-shaped supply of grass is created, ensuring a continuous supply during the second rotation

The simple rules are:

Dry farms:

- Turnout early to mid-February
- At least 30% of the farm grazed by 1st March
- 60% of farm grazed by 17th March
- 100% of farm grazed by the end of the first week in April

The date the first rotation ends will vary from farm to farm. Your specific Magic Day (end of the first rotation) can be established over a number of years by walking your farm and measuring farm covers and grass growth which will help build up a record of what to expect from year to year.

Heavy/slow grass growing farms:

- Turnout late February / early-March
- 30% of the farm grazed by 10th March
- 60% of the farm grazed by 27th March
- 100% of farm grazed by mid-April

In general the dates by which a certain proportion of the farm should be grazed are 10-14 days later on heavy farms compared to dry farms.

It is important that these targets are achieved as it will ensure there is sufficient grass available by the start of the second rotation. By grazing a certain amount per week a wedge shape of grass supply can be achieved. For example: if all animals are let out to grass a couple of days before 30% of the farm should be grazed it means that all these paddocks are re-growing at the same rate. There will be a shortage of grass at the start of the second rotation and then too much grass as all paddocks reach their target pre-grazing yield at the same time.

Figure 2.6. Example of a Spring Rotation Planner of a 40 ha dry farm where turnout date is 1 February and the first rotation ends 5 April

Week	Total area grazed by week ending (%)	Cumulative area grazed (ha)/ week ending	Pregrazing Herbage Mass on April 5th (kg DM/ha)
1st to 7th Feb	7	2.8	800 - 1,200
8th to 14th Feb	14	5.6	
15th to 21st Feb	21	8.4	
22nd to 28th Feb	30	12	
1st to 7th Mar	45	18	400 – 800
8th to 14th Mar	60	24	
15th to 21st Mar	73	29.2	
22nd to 28th Mar	87	34.8	100 - 400
29th Mar to 4th Apr	100	40	

The template of Figure 2.6 can be photocopied and used every spring. For example if the farm is 50 ha then 50 (ha) multiplied by 7 and divided by 100 (i.e. 7%) is the area which should be grazed by the end of week 1. Using this example 3.5 ha should be grazed by the end of week 1 – this means 0.5 ha should be grazed every day for the first week (3.5 ha divided by 7 days). Each week can be worked out in the same way. Note: for the first 3 weeks the weekly area of the farm which should be grazed is 7%, from week 4 onwards the area per week increases.

Spring grazing for different animal types

Beef

Research work has shown that animals turned out early to grass in early spring have 6% (+23kg) higher carcase weight than animals turned out later in spring. This could equate to close to €60 to €70/head.

Turnout of animals should take place during periods of dry weather, with good underfoot conditions this will give animals an opportunity to 'settle' and start grazing properly. Early turnout will reduce the accumulation of surpluses during the main grazing season.

Dairy

Each extra day at grass in spring is worth €2.70/cow/day – this comes from reduced feed costs and labour input (slurry spreading etc.) and an increase in milk protein concentration.

Dairy cows should be turned out directly post calving. Cows should start grazing lower covers first to get them used to a grass diet again. After a week or 10-days they can start grazing heavier covers. Covers over 1600 kg DM/ha (>4cm) should be grazed by early March at the very latest.

Feeding the dairy cow in spring

- Cows reach peak lactation 6-8 weeks after calving
- Peak dry matter intake (DMI) occurs 10-12 weeks after calving
- Cows use their fat reserves to make up the energy deficit in early lactation ('milks off her back')
- Cows calving into a grass based system have a total DMI of 8-11 kg DM/cow/day during the first week after calving – this increases by 0.75 – 1 kg DM/cow/day up to peak intake which is 16 – 18 kg DM (Figure 2.7)
- Care should be taken to ensure that cows do not lose more than half a unit of BCS as cow fertility will suffer if this occurs
- Winter milk herds can reduce the rate of concentrate supplementation by 1 – 2 kg DM when grass is included in the diet

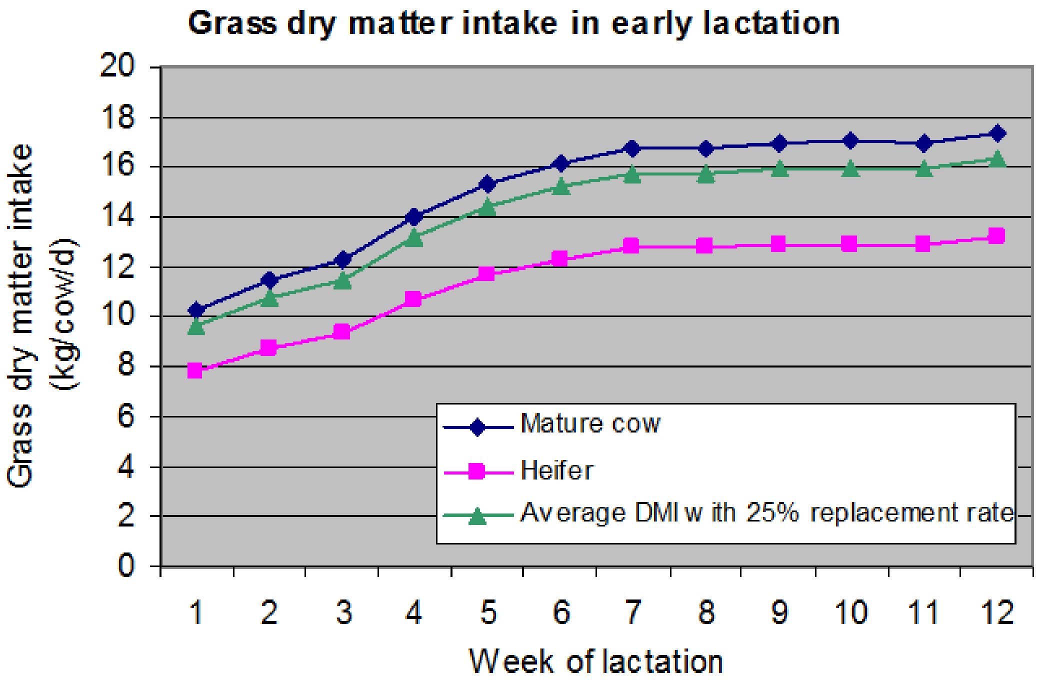


Figure 2.7. Grass dry matter intake in early lactation

Supplementing the dairy cow at grass

- Quantity of grass available on the farm will dictate how much supplementation is offered to the cows
- It is essential that as well as following the spring rotation planner the farm is walked weekly and a cover completed so that decisions on grass availability, supplementation level etc. can be made.
- Supplementation required = cows energy requirement – grass energy intake
- In general the maximum level of supplementation for freshly calved cows in spring should be 6 kg DM, if the deficit is greater than this high quality grass silage should be offered in combination with concentrate
- As a general rule 6 – 8 weeks after calving 15 kg DM of grass plus 3 kg DM of concentrate is sufficient for peak milk solids yield of 1.8 – 2.0 kg/cow/day, concentrate level can be reduced depending on grass supply
- The protein content of early spring grass is high (>20%), high protein concentrates are not required when the majority of the diet is made up of grazed grass
- If supplementing to reduce the risk of grass tetany make sure to check the concentrate composition so that the correct rate is being fed to the covers to offer protection. Cows require 30g of magnesium or 60g of calcined magnesite per day. Magnesium can also be supplied through pasture dusting or through treated water

Sheep and goat

The aim is to have enough grass to match ewes demand until supply increases and matches demand (magic day). For an early/mid-March lambing flock an opening farm cover of 600-700 kg grass DM/ha or 20-25 days ahead is recommended. Why?

- 10 ewes/ha with average demand of 2.5 kg DM /head /day in early lactation
- 10 x 2.5 = daily requirement of 25 kg DM/day
- 650÷25 = 26 days ahead

If we estimate average grass growth rate of 15 kg DM/ha/day in early/mid-March this will add another 10-15 days so we have 35-40 days which should extend to mid-April (magic day).

Feeding of sheep and goats is often based on information derived from cattle. But they are different in many metabolic features (see Table 2.2).

Table 2.2. Metabolic features of cattle, sheep and goats.

	Cattle	Sheep	Goats
Live weight (kg)	600	45	45
Metabolic weight (MW) ($MW=W^{0.75}$)(kg)	121.2	17.4	17.4
Net Metabolic Energy (NME) (Kcal/kg $P^{0.75}$)	70	65	56
Total Net Metabolic Energy (tNME) (Kcal)	8484	1131	975
Volume of the digestive system* (VDS) (ml)	90000	6750	6750
Digestive capacity (DC)(=VDS/tNME)	10.6	6.0	7.7

*VDS equals 13-18% of total body volume

The utilization of pastures by sheep and goats depends on several parameters, in particular by their dry matter intake and the quality and quantity of pastures.

Low-speed ruminal degradation feeds (cellulose, hemicellulose, insoluble proteins and starches) having a longer time of food retention in the rumen and are better utilised by cattle than by goats and sheep. This because cows have a larger rumen than sheep and goats. Sheep and goats balance these disadvantages by:

(i) a higher voluntary intake of feed (5-7% of their weight vs 3-4% in cattle). Other things being equal, sheep and goat show a DM intake of 5-5.5 kg DM per 100 kg live weight vs 2.8-3.2 in cattle during lactation.
(ii) selecting species with a higher rate of rumen degradation (less fibrous plants, leaves, shoots) in pastures. This option is facilitated by the particular conformation of the muzzle and the greater lingual and labial mobility than cattle.
(iii) Sheep and goats take much longer than cattle to ingest and ruminate (about 10 times more). In fact, they have a less powerful chewing activity, and they need to grind foods finer to allow transit in the digestive system. Consequently, intake is more influenced by fiber dimension in sheep and goats than in cattle.

The DM intake depends on the metabolic weight of the sheep or goat: during full lactation, it varies from 2.5 kg DM in a sheep of 50 kg (equal to 5 kg 100 kg^{-1}) to 2.7 kg DM in a sheep of 60 kg (equal to 5.4 kg DM 100 kg^{-1}). Dairy sheep have usually higher DM intakes than meat sheep. In dairy sheep, the voluntary intake changes in relation to the physiological stage: in a sheep (50 kg) the voluntary intake changes from 1.6 (in the last part of pregnancy) to 2.4 kg DM (at the 2-3 lactation month). At the same lactation stage, DM intake depends on milk production. During pregnancy, DM intake depends on the number of lambs and becomes lower with the increasing number of lambs. Adverse environmental factors during grazing can influence the voluntary intake (wind, sun, rain, cold temperatures). The voluntary intake in sheep and goat is also influenced by the quality of the pasture (Table 2.3), and especially by its digestibility: the higher the digestibility, the higher the intake.

Table 2.3. Effect of different characteristics of grass on voluntary ntake.

Feed	Voluntary DM intake (kg 100kg LW)
High quality pastures	5.0
Medium quality pastures – excellent corn silage – high quality haylage – high quality hay	4.0-5.0
Poor pastures and green forage – medium quality corn silage/haylage/hay	2.5-4.0
Very poor pastures and green forage - poor hay/silage - straw	1.7-2.5

Note that sheep and goats often are bred in hilly and mountainous areas and have high energy requirements for walking in addition to basic energy requirements (0.53 UFL for a 40 kg sheep, and +0.09 UFL every +10 kg). On average, it is required +25% energy for grazing in good pastures and higher requirements in poor and not homogeneous pastures.

The optimal height of pastures for sheep is about 6 cm in spring with continuous grazing and 7-8 cm with rotational grazing to keep herbage green, leafy and with a good nutritional value.

<u>Issues</u>

- Insufficient area closed in autumn to build covers for spring
- No N applied to boost covers and enhance March growth rates

2.4.2 Summer

Managing Grass Supply: Balancing grass supply to grass demand

The key to mid-season or summer grazing is to ensure a constant supply of high-quality grass ahead of the herd. High performance can be achieved from a grass-only diet once the correct pre-grazing yield is offered. Allowing pre-grazing yield to exceed recommended levels leads to a decline in grass quality, resulting in poor milk solids yield or poor rates of weight gain.

Finishing the first rotation on time is critical for mid-season grass supply and quality. It will ensure that grass will be more easily managed in the second and subsequent grazing rotations. Finishing the first rotation too early will mean animals are grazing on too short a rotation from April onwards and grass will be in short supply. Finishing the first rotation too late means there will be surplus grass, post-grazing residuals will be difficult to achieve and quality will be affected for the rest of the year. The biggest problem on farms is that the first rotation starts and ends too late.

Avoid wasting offered grass to the herd

Too often excessive grass is offered to the grazing herd. High grass utilisation (>80%) is possible when pre-grazing yields are at levels that the grazing animals can graze out well.

The key focus during the main grazing season is to offer high-quality/leafy material to the grazing herds as often as possible. Grazing animals respond positively to high-quality grass and it is far easier for them to graze swards of range 1,400-1,600 kg DM/ha (8-10cm) than swards of 2,000-2,500kg DM/ha (12+cm).

General points

- Grazing to 3.5-4cm in the first rotation provides a platform for excellent quality re-growth in second and subsequent rotations

- The ideal pre-grazing yield for maximum animal performance in summer is 1,400-1,600kg DM/ha (8-10cm)
- Under-grazing leads to a greater proportion of stem. This will lower grass quality and animal performance.
- Avoid turning stock into too heavy covers. React quickly to surplus grass and harvest as baled silage.

Grass Quality

Grass quality is indicated by grass digestibility. Maintaining high quality pastures with a high proportion of leaf is critically important during the summer/main grazing period.

- Grass quality influences dry matter intake and production performance
- High digestibility grass has a high intake potential and a high energy content
- High digestibility grass is characterised by
    - high leaf content, low true stem content
    - high protein concentration, medium fibre concentration
    - short-medium regrowth interval, low-medium pre-grazing herbage mass

High production performance from grazing livestock has a major influence on farm profitability. This is achieved by ensuring high intakes of high quality grass. Grazed grass when correctly managed is of high nutritive value. Grass quality, as indicated by organic matter digestibility (OMD), can be maintained at a high level throughout the grazing season under good management practices.

Digestibility is the biggest factor determining the energy content of grass. The digestibility of grass exhibits a characteristic pattern of change during the year. The highest values are obtained in spring (80 - 85%), when the grass plant is leafy; lowest in mid-summer (78-80%) when the grass plant is in a reproductive (flowering) phase; and it is intermediate in autumn (79 - 81%).

When the quantity of grass is not limiting, the primary factor influencing intake by grazing animals relates to the digestibility of the grass available. The changes in digestibility are associated with changes in the amount of green leaf, mature stem and dead material. As the grass plant matures, the proportion of leaf to stem decreases and this is associated with a decrease in the ratio of cell contents to cell wall constituents especially in the stem fraction.

Green leaf is highly digestible. Animals will select green leaf over stem. Grass will be low in digestibility when it has a lot of stem, flower heads and dead material. The problem with this type of grass is that the intake will be low because animals don't like the material offered. They find it difficult to graze and they digest it less, i.e. they extract less nutrients from it.

Visual assessment

A practical measurement of grass quality is a quick assessment of grass being offered to animals. A small representative sample of grass can be cut at the predicted post-grazing height. This can then be visually assessed for sward morphology:

What colour is the sample? Bright green swards (more leaf) are an indicator of high digestibility, while pale green/ yellow swards (more stem and dead material) are less digestible.

What is the texture of the sample? Green leaf has a soft texture which is easier for animals to consume and digest, while stem has a coarse texture which is more difficult for animals to consume and digest.

What is the leaf to stem ratio? A manual separation of the sward components can be used to give an indication of grass quality. Well managed grazed swards will contain between 70-80 % green leaf, 15-20% green pseudostem and less than 5% mature stem and 5% dead material. This is important as every 5% increase in sward leaf content results in a 1% increase in digestibility.

Leaf stage / pre-grazing herbage mass

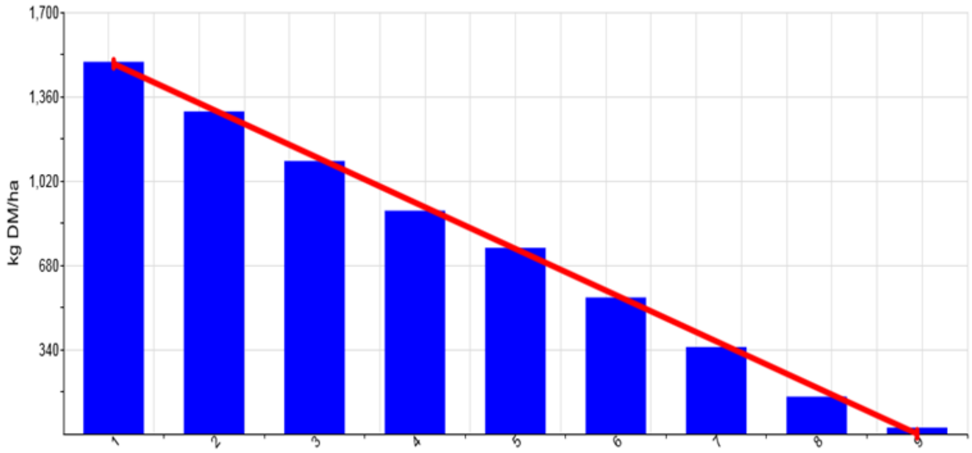
Well managed grazing swards which are grazed between 1400 - 1600 kg DM/ha pre-grazing herbage mass (PGHM) are generally at the 2.5 to 3 leaf stage of growth. This means that the third leaf on a tiller is emerging or fully emerged. Grazing at this stage of growth is optimal as it maximizes green leaf content in the sward and avoids leaf senescence which would occur if the sward is left to grow. Grass quality can be maintained by grazing swards with a PGHM to a post grazing sward height of 4cm throughout the summer.

Managing grass supply during the main grazing season

The objective during the main grazing season (May to August) is to achieve high performance from a grass-only diet. High animal performance will be achieved by maintaining a consistent grass supply for the herd and monitoring farm grass cover weekly. This monitoring will be the basis for a grazing wedge. This grazing wedge will allow decisions to be made to alter grass supply early; for example, adjusting stocking rates or removing surplus grass.

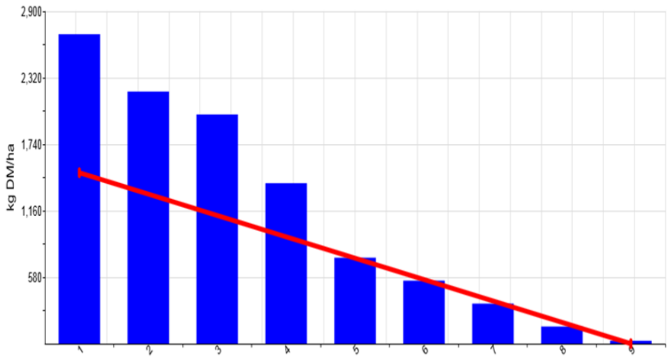
The grazing wedge: Understanding your wedge

The line on your wedge graph is drawn from the ideal pre-grazing yield (1400 – 1600 kg DM/ha) to the target post-grazing residual (100 kg DM/ha). A perfect wedge, such as the one below, is where all the paddocks are meeting the line – that is there are no surpluses (paddocks above the line) and no deficits (paddocks below the line), everything is on target. Frequently this is not the case. The following sequence of graphs gives various scenarios that may arise and also outlines actions that should be taken to correct surpluses or deficits.



Surplus wedges

From this wedge it is evident that this farmer has a surplus on the farm, the first four paddocks are over the demand line. Pre-grazing yield is well above the target of 1400 – 1600 kg DM/ha. Residuals (post-grazing yields) are being achieved in this example but frequently when grazing high pre-grazing yields paddocks are not grazed out properly and residuals are too high which can affect subsequent sward quality.

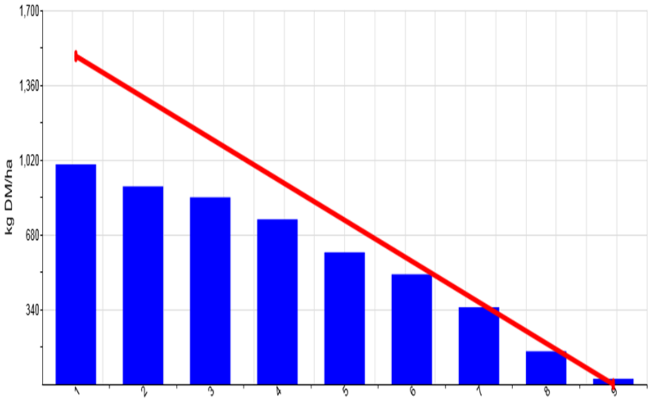


Dealing with surplus grass:

- Remove surplus paddocks as silage - this should be completed as soon as possible (or once the paddock reaches 2,500 kg DM/ha) so that the paddocks will be back in the grazing rotation as quickly as possible
- Don't delay the reaction to high grass growth
- If the grass in the paddock is not too 'strong' get other animals to graze it e.g. heifers/dry cows.
- Don't increase stocking rate too much on the grazing area, by closing too many paddocks for long term silage
- Caution should be exercised so that excessive grass is not removed resulting in a deficit
- Removing surplus grass as soon as it is identified will result in the area being included in the grazing round and therefore making it available to cope with a slowing of pasture growth

Deficit Wedges

The next graph is an example of a deficit i.e. not enough grass available to meet target pre-grazing yields.

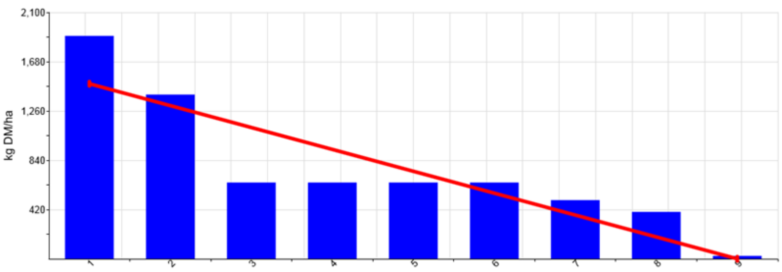


It is clear there is a large deficit on this farm, the first six paddocks on the graph are below their target. The farmer is currently grazing pre-grazing yields of 1,000 kg DM/ha, well below the 1400 to 1600 kg DM/ha pre-grazing yield target. Extreme action will need to be taken to rectify this problem. Weekly measurement and acting on the information recorded could have prevented this situation arising as the farmer would have been able to see this deficit occurring before it actually happened.

Dealing with deficit:

- In all cases before ‘magic day’ (day when grass supply equals grass demand) do not speed up the round
- After ‘magic day’ consider increasing the grazing area/day during the deficit period if soil temperatures have continued to rise and pasture growth is increasing
- Supplement with concentrate or grass silage (preferably high quality baled silage that was previously removed as surplus as it will be of better quality than pit silage)
- Re-graze area closed for silage once the pre-grazing yield is not excessive. A strip wire should be used in this situation

Difficult to interpret wedges



This farmer has a surplus in the first two paddocks, followed by three paddocks which are below target, while the next three are above target. In this situation the farmer should graze the first paddock provided the grass is of high quality. This will give the paddocks below the demand line more time to grow and achieve their target pre-grazing yield. However, if they are below target at grazing the paddocks following behind should have sufficient grass to ensure a deficit does not occur on the farm. The farmer should also ensure that post-grazing height is being maintained in each paddock. This situation is best dealt with by walking the farm in a few days’ time to see how much grass is growing and if supplementation needs to be introduced or not.

The key grassland management guidelines for this period are:

- Aim to consistently offer animals a sward where there is green leaf to the base and very little stem
- Ideal pre-grazing yield targets are 8 - 10 cm (1300 - 1600 kg DM/ha). Maximum pre-grazing yield is 10 - 11 cm (1600 - 1800 kg DM/ha). If this is exceeded, excess grass should be removed as baled silage (depending on grass supply)
- Rotation length should be maintained at 18 - 21 days
- Early identification of surpluses by measuring grass weekly may reduce or eliminate the requirement for topping
- Use the grass wedge to identify grass surpluses and deficits
- These surpluses can be removed as round bale silage, which will replace the necessity to top pastures. They will also act as a source of extra feed if the winter is unexpectedly extended.
- Average farm cover per cow needs to be maintained at 160-190kg/DM/day.
- If pastures have high post-grazing residuals (400- 500 kg DM/ha) or high post grazing height (>6 cm), they should be topped. Pasture topping should take place early (mid-May) rather than late in the season.

Sheep

Key guidelines to maintain quality in pasture grazed by sheep during the mid-season or summer months

- Quality versus quantity
- Pre grazing height = 7- 9cm (1000 -1500kgDM/ha)
- Leaf = digestibility
- Post grazing height
- Pre weaning : 4.0-4.5cm
- Post weaning: 5.0-5.5cm
- Ewes: 4.0-4.5cm

2.4.3 Autumn

There is a lot of potential to make better use of grass on farms in autumn. Every extra tonne of grass utilised is worth €173/ha. Utilising extra grass and lengthening the grazing season should be your key objective in autumn. The focus of autumn grazing management is to increase the number of days at grass and animal performance, but also to set the farm up during the final rotation to grow grass over winter and provide grass the following spring.

There are two key autumn periods:

- Period of autumn grass build-up
- Managing the final rotation.

Generally, rotation length should be extended from 1 August. The focus of this period is to gradually build pre-grazing herbage mass, targeting maximum covers of 2,000kg to 2,300kg DM/ha in mid-September. Pre-grazing covers >2,500kg DM/ ha are difficult to utilise and should be harvested as surplus (round bales). Surplus paddocks should be removed in August. Removing paddocks after the first week of September should be avoided if possible; a September harvest is too late as paddocks do not have enough time to re-grow to make any contribution in the last rotation. By achieving the right farm cover at the right time, decisions are easier to make. Many farmers fall into the trap of building cover too late and are pushed into harvesting excess grass in September.

Autumn nitrogen application

Grazing stocking rates are quite varied on farms, which has a huge effect on feed demand. As the Nitrate Directive deadline date for nitrogen application is 15 September in Ireland, farmers must decide in late August/early September what level of nitrogen application they will apply to ensure sufficient grass growth for the final rotations. Farmers with a high grass demand in October/November, who have their nitrogen applications up to date by August, should consider applying a blanket application by mid-September. The amount to apply may vary, and will depend on feed supply. Only blanket spread nitrogen if the farm is under target for grass. Spreading excess nitrogen in autumn is wasting money as the soil is naturally releasing nitrogen.

Preparing for the final grazing rotation: August- December

The aim of this period is to maximise the amount of grass utilised from September to December while, at the same time, finish the grazing season with the desired farm grass cover. The farm grass covers or amount of grass grown over this period will depend on stocking rate, level of supplementation and autumn nitrogen application. The following guidelines should be used:

- Rotation length should be increased from 25 to 30 days in mid/ late August to 35 to 40 days in late September.
- Last grazing rotation should be 30 to 40 days with first fields rested from 5th - 10th October.
- Closing should be a week to 10 days earlier on heavier type soils.
- Choose drier paddocks, paddocks close to the yard or sheltered paddocks to close first so that they will be the first ones grazed in spring.
- Close wettest paddocks next in the rotation followed by the remaining paddocks.
- Aim to have 60% of the farm grazed by the first week of November with the remaining 40% grazed by late November/early December (these dates change, depending on location).
- Aim for an average farm cover of (1,000kg DM/ha) by late September.
- Pre-grazing yields should not exceed 2,000kg to 2,300kg DM/ha. Very high pre-grazing yields will result in poor pasture quality and poor utilisation by the grazing animals.
- Avoid grazing very high pre-grazing yields in last rotation (>13cm; >2,500kg DM/ha). As well as the problems outlined above, high pre-grazing yields in the last rotation have been shown to have a very detrimental effect on subsequent winter/spring grass growth.

- Pastures should be grazed well (3.5cm) in the last rotation to encourage autumn/winter tillering. Use younger or lighter animals or dry cows to achieve this residual in wetter conditions.
- Closing grass cover in early December should be, on average, 650-700 kg DM/ha.

Autumn 60:40 rotation planner

The autumn rotation planner is a tool to help extend the grazing season into late autumn and, if followed, it will ensure that paddocks are set up correctly for grazing the following spring. The 60:40 plan is based on having proportions of the farm closed by certain dates. These dates will vary slightly across the country and depend on soil type and the amount of grass that is likely to grow over the winter. The 60:40 autumn rotation planner will not inform you if you are grazing paddocks that have too much grass and it will not tell you if you are not achieving desired post-grazing residuals. You will have to gauge that by walking through your paddocks or fields and assessing either visually or by measuring. The objectives of the autumn rotation planner are:

- To keep grass in the diet of the animals for as long as possible.
- To set up paddocks for grazing the following spring

The simple rules are:

- Dry farms – start closing 5th – 10th October; 60% of the farm grazed by first week November; remaining 40% grazed by 1st December.
- Heavy or slow grass growing farms – start closing 1st October; 60% of the farm grazed by 20th October; remaining 40% grazed by mid-November.

Figure 2.8 shows the difference between a dry farm (closing 10 October) and a heavy farm (closing 1 October). For a dry farm, 60% should be grazed within four weeks and the remaining 40% in the next four weeks. On a wetter farm, this adapts to 60% grazed in four weeks and the remaining 40% in three weeks. Over time, groups of animals can be housed, reducing the number of animals at grass.

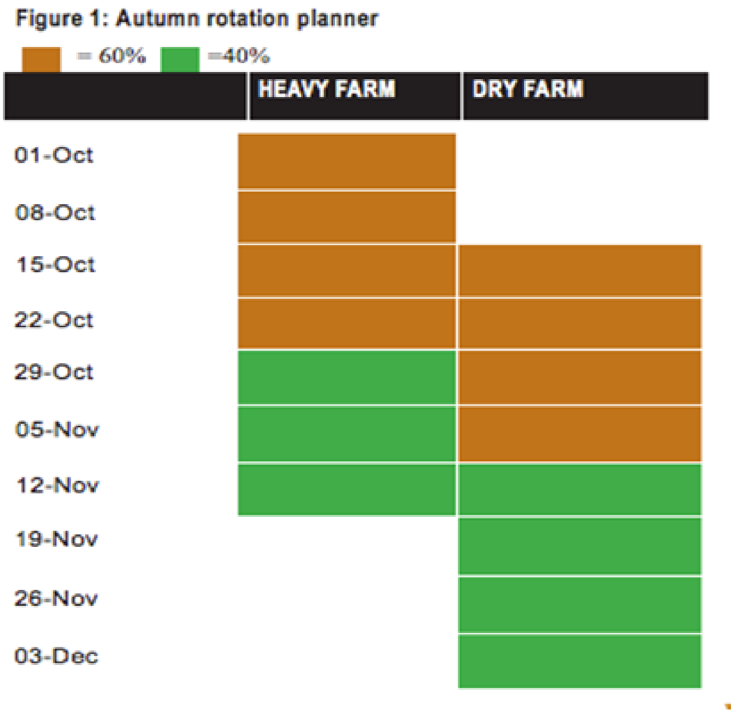


Figure 2.8. Examples of autmn rotation planner.

<u>To managing a wet autumn</u>

- A flexible attitude – don't allow poaching.
- Use most sheltered and driest paddocks when grazing in wet weather.
- Strip grazing or block grazing can be used during wet weather to ensure minimal damage from poaching. Use one section per day to get the most from the grass.
- Where possible, use a back fence. This will help to protect re-growths and prevent soil damage.
- On/off grazing can be practised to reduce poaching damage and keep animals at grass for longer.
- Have multiple access points into a paddock so that grazing animals do not have to use the same entrance. If you don't, create a 4ft to 5ft grass roadway on a fence line to get animals to the back of the paddock.
- Strategically place water troughs in the paddock so that they will service several strips or blocks when a strip wire is being used.
- Graze paddocks with heavy covers from the back of the paddock on the sheltered side.
- Change grazing break daily or every two days.
- Change animals at the same time; give them a routine

<u>Dairy</u>

The main aim during this period is to maximise the amount of grazed grass in the dairy cow's diet. There are occasions when supplementation may be necessary such as:

- To reduce demand for grass so covers can be built helping to extend the grazing season

- To maintain milk lactose levels
- To maintain milk production; milk price will have a large influence over this
- To increase cow BCS before drying off

Supplementing the dairy cow in autumn

If grazing full-time 2 – 3 kg DM of a high energy low-protein concentrate is sufficient. If cows are indoors on grass silage (68 – 70 DMD) 3 – 4 kg DM of an 18% crude protein concentrate will support 10 – 12 litres of milk (0.8 – 1.1 kg milk solids).

Sheep

- Grass year starts in Autumn
- Closing from late October
- Swards should be rested for 120 days over winter.
- Match autumn closing dates to expected lambing dates to match spring grass supply to demand

2.5 Farm Infrastructure

Fergus Bogue, Michael O'Donovan (Teagasc), Leanne Aantjes, Agnes van den Pol-van Dasselaar (Aeres)

The design and layout of grazing infrastructure is crucial to overall herd performance as it can allow more days at grass and hence greater profitability. It comprises three factors:

- Paddock system
- Road system
- Drinking water infrastructure

How do I create an efficient paddock system?

- Get a map of the farm with areas for each field/paddock.
- Decide on the number of paddocks required; this will depend on whether the paddock will be used for one, two, three or more grazings.
- Determine most suitable road layout to service each paddock.
- Determine most appropriate water trough(s) position in each paddock.
- Allow for multiple entrances into each paddock.
- Ideally keep paddocks square/rectangular, ideally depth: width ratio should be 2:1.

Key risks with respect to paddock layout

- Long narrow paddocks – too much walking over ground to graze the end of the paddocks can result in excessive risk of poaching.

- Large paddocks – grass regrowths are grazed if over 3-4 grazings per paddock are needed. Using a strip wire to divide the paddock requires extra labour during the main grazing season and it reduces milk solids.
- Small paddocks – insufficient grass for one grazing, extra water troughs are required.
- Farmers expanding should use strip wire until they decide how many cows they will milk.

Alternatives to a paddock system

Have no set paddock system – use temporary wire for all grazings. The advantage is that the grazing area can be adjusted throughout the year and that surplus grass/silage is more easily harvested.

Setting up the farm for grazing

- Get a farm map with exact areas of each paddock.
- Number every paddock.
- Create a good network of roadways
- Roadways should follow land contours where extreme and be wide with gentle sweeping bends (especially for larger herds)
- Locate roadways on the sunny windy side of a ditch, hedge or tree line.
- Avoid putting races directly through springs or swampy ground.
- Plan underpasses carefully to allow for gentle slopes into and out of the underpass for drainage.
- Where possible create multiple access points which will help with grazing during wet weather
- Have several gateways between adjacent paddocks.
- It is a good idea to have easy to access cut-off switches on electric fences.
- Have multiple water troughs or fitting where water troughs can be installed (this allows flexibility when putting up strip wires)
- Keep a record of dates when grazed, fertilised, topped and cut for round bale silage.
- Find out the reseeding history and soil fertility of each paddock.
- Record varieties sown when reseeding
- Soil test every 2 years.
- In drystock systems assign specific paddocks to stock, i.e. cow paddocks, fattening stock paddocks, leader follower paddocks.
- Maintaining a small number of grazing groups will allow the total number of paddocks required to be maintained at a manageable level. This can be done by grazing steers and bulls together and by mixed grazing of cattle and sheep and leader/follower systems

Paddock sizes

Proper subdivision of grazing land into paddocks is essential to be able to successfully manage pastures and achieve desirable rotation intervals. Paddocks must be connected with an efficient roadway system so that the herd can move easily. The ideal paddock system should include:

- About 20 to 23 full sized paddocks and a few small paddocks near the parlour/sheds.
- The roadways/lanes from the parlour/farmyard to the paddocks should be wide smooth and as short a distance as is practical.
- The paddocks should be big enough so that there is sufficient pasture for the full herd for 24-36 hours when the pre-grazing cover does not exceed 1400-1600 kg DM/ha and on a 21 day grazing rotation.
- Paddocks should be rectangular to square in shape and wetter paddocks should have longest sides running adjacent to the races to avoid poaching in wet weather.
- Alter paddock shape to facilitate stock movement into and out of the paddock i.e. stock move downhill to exit paddocks.
- Main paddock gateways to be angled to the roadway with at least two gateways for each paddock.
- The paddocks should be numbered with a tag on the gate and on a map of the farm.

<u>Creating paddocks</u>

1) Use the maps to consider several different ways of laying out the farm and consider the positives and negatives of each one.
2) Chose the option which ticks the most positives and the least negatives.
3) Mark the layout on the ground with marker pegs. Use different colours for roadway edges and paddock boundaries.
4) Re-consider the layout both from the practicality of construction and operation and from the perspective of the animal. Does this actually make sense?
   - Are the paddock entrances in dry ground?
   - Are the paddock entrances in the downhill corner of the paddock?
   - Is the slope of the roadway less than 10%?
   - Will the race disrupt normal flow of water down a slope?
5) Re-align the markers on the ground to correct for the issues identified in 4 above
6) Record the final layout on an accurate map and make lots of copies. Get a very large one made that is suitable to put on a wall
7) In beef systems the ideal size for a 40-cow suckler herd is 2ha/paddock

<u>Sheep</u>

Paddock system/Rotational grazing

Why? Control = increased grass utilisation, increased grass growth and increased grass quality

- Rotation grazing - Minimum of 5 Paddocks
- Provide high quality leafy grass
- Average residency of 5 days per paddock

Practical level

- Average 100 ewe flock SR 10 ewes/ha (4 ewes/ac)
- 5 grazing divisions of 2ha (5ac) each
- Can be permanently fenced and each split

Or

- Boundary set up to allow 5-10 temporary divisions as needed
- Allows flexibility and control

Why 2ha?

- Example week 9 of lactation (mid may) daily requirement of ewes is 3kg DM/hd/day. Lambs req 0.7 kg DM/hd/day. 3 + 0.7 x 1.6 = 4.12kg DM/ewe and lamb unit/day. 4.12 x 100 = 412kg DM/ha/day = flock demand
- Pre grazing yield = 1200kg DM/ha x 2ha = 2400kg DM available
- 2400 kg/412kg = 5.8 days to graze paddock
- Paddock cover and flock demand will vary so 2ha per 100 ewes is good guideline figure
- Ideally this would be offered 1ha at a time 2-3 days grazing to increase utilisation and improve regrowth potential

Water

A water supply in each grazing division is necessary. Ideally, every paddock should have a permanent water supply. Placing troughs across fences reduces the number required. If using a temporary wire to strip or block graze, strategically place troughs in the field so that animals do not have to walk back over the grazed area for water. Alternatively have multiple fittings where water troughs can be installed (this allows flexibility when putting up strip wires). Water systems should:

- Deliver sufficient water to meet the stock needs during greatest demand. This means that the amount of storage and flow rate should be adequate, so that any trough never be less than 2/3 full.
- Use taps in easy to find, key locations to split the water system into sections so that it is quick and easy to shut off sections of the farm.
- Make it easy to identify, locate, isolate and repair leaks, using easy to see storage
- Keeping water troughs in the centre of the paddock allows for livestock to be further split with temporary fencing.
- Alternatively, water troughs can be fitted with a long length of water piping and the water trough can be moved between grazing areas within the one paddock.
- Water supply/pressure will often dictate the size and type of water trough used.

Farm Roadways

Roadways are an obvious advantage as they allow easy access to paddocks and avoid soil damage. The objective is to have animals walking comfortably at 3 km/hr with their heads down so that they can see where they are placing their front feet (the back feet will step into the same place). Actual animal walking speed is determined by walking surface, animal training and animal fitness. Roadway maintenance:

- It is essential that no water is allowed to pool on the race surface
- Fill pot holes as soon as they form
- Remove any build-up of material at the sides of the race that will prevent water running off.

- Restrict the speed of tractors, quads and other farm vehicles on farm roadways
- Keep vegetation trimmed well back to allow in light and wind onto farm roadways

Temporary fencing

Temporary electric fencing should be used to divide larger fields to give the required paddock size, especially when grazing silage fields during the first rotation.

3. Hay and silage making

3.1 Cutting management and hay making

Giovanni Peratoner (Laimburg Research Centre), Alain Peeters (RHEA Research Centre)

Cutting as a form of grassland management

By cutting grassland, the whole aboveground biomass accumulated by each growth cycle is removed at once above a certain cutting height. As a difference to pastures, animal-mediated factors such as selectivity, trampling and deposition of excreta do no longer affect the vegetation. Manure from the cattle can be spread evenly on the fields. Depending on the method used to mow the plants, a certain mechanical disturbance to the soil due to the machines and implements used is caused. Unless only small amounts of forage are harvested and immediately fed to the animals, the harvested herbage must be conserved. This means that it must be brought as soon as possible to a stable state, thus allowing preservation, for minimizing losses of nutrients and quality decrease during the conservation process.

Cutting height

A cutting height between 5 and 7 cm should be targeted. Such a cutting height allows the maintenance of critical amounts of plant tissues capable of photosynthesis for regrowth. At lower cutting heights, plants have to mobilize important amounts of nutrient stocks in their root system. This induces a higher sensitivity to drought, delayed regrowth and lower yield at the following cut. Cutting too close to soil surface on an irregular soil surface may lead to scalped swards, which results on both vegetation and equipment damages and on soil contamination of herbage. Moreover, for haymaking, if the drying process takes place on the field, too short stubbles would fail to maintain some distance between the overlying swath and the soil, causing a poor air circulation below the swath and thus a retard in drying. A further increase in cutting height (i.e. to 10 cm), on the other hand, has been shown to not improve quality, but to decrease forage yield. Avoiding soil contamination during harvest is a pivotal issue, relevant to all forms of forage conservation. This is achieved by driving carefully, taking soil conditions under consideration (avoiding mechanical damage of the sward, which is difficult on steep slopes and under moist conditions) and setting the right cutting height (to be set on solid ground) in order to avoid soil scalping. The right working height (3 cm on solid ground) of all other implements to be used (conditioners, tedders, windrowers, loaders) must be accurately set as well.

Harvesting time

With the progress of the phenology of the plants, and especially with the start of the generative stage, there is an increase in forage yield and a concomitant decrease of forage quality. The latter is due to both a proportion increase of fibre-rich tissues (typically stems) and in general to the lignification of other tissues due to senescence processes. Maximum yield is achieved at a later stage, after flowering, but then forage quality is low since forage quality moves in the opposite direction of forage yield. The choice of the optimum harvesting time is a compromise between forage yield and quality. The choice of the correct harvesting time is particularly important at the first cut, which is the one contributing usually most to the annual yield (Table 3.1). The duration of the growing season, the harvesting time at the first cut and the time needed for regrowths to accumulate enough herbage for the next cuts (usually five to eight weeks) determine the cutting frequency over the whole growing season. At cutting frequencies between two and four cuts per year, the contribution of the first cut varies between about 40 and 60% and decreases with increasing cut frequency.

Table 3.1. Example of contributions of different cuts to the annual yield. Sources: www.gruenland-online.de for 5- and 6-cut meadows, and means of a ten year-series at two experimental mountain sites in South Tyrol for the other cut frequencies (Laimburg Research Centre, unpublished data).

Cutting frequency (cut/year)	Cut	Contribution to yearly yield (%)
2	1st	62
	2nd	38
3	1st	47
	2nd	28
	3rd	26
4	1st	39
	2nd	20
	3rd	21
	4th	21
5	1st	30
	2nd	20
	3rd	20
	4th	17
	5th	13
6	1st	30
	2nd	25
	3rd	15
	4th	15
	5th	10
	6th	5

Moreover, it is at the first cut that the proportion of reproductive stems is the highest, especially in systems with a limited number of annual cuts. This results both in a fast yield increase and a corresponding quality decrease (example for mountain meadows can be found in Figure 3.1). These changes of forage quality over time are less pronounced for regrowths (example in Figure 3.2). Even with a clear choice of optimum cutting period, unfavourable weather conditions can cause considerable deviations of the harvesting time from the optimum. For this reason, conservation methods reducing the dependency on weather results such as silage and haylage can be alternatives to hay making.

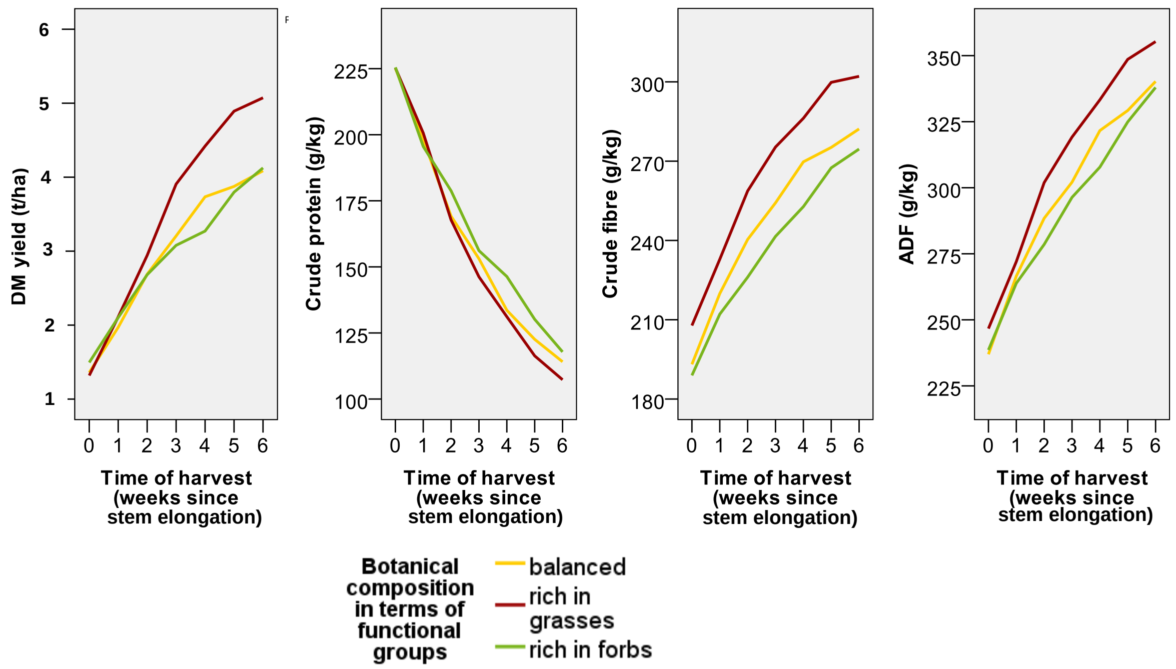


Figure 3.1. Change over time of forage yield and quality during the first growth cycle of mountain meadows. Means of 202 environments (site x year) in South Tyrol (NE Italy) at altitudes between 660 and 1660 m a.s.l. (Laimburg Research Centre, unpublished data).

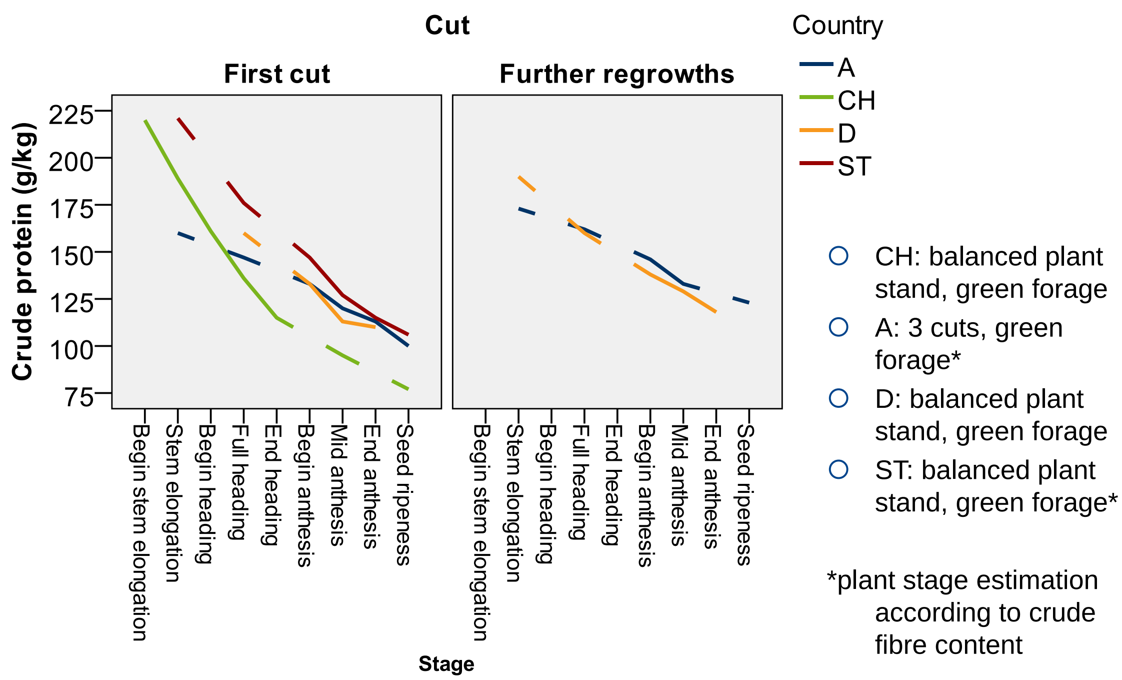


Figure 3.2. Changes of crude protein content depending on the average phenological stage of grasslands according to tabulated forage values of four Alpine countries (adapted from Resch *et al*., 2006, Daccord *et al*., 2007 and DLG, 1997).

Haymaking

Haymaking is a physical process based on drying herbage in order to produce hay. The aim is to reduce, as quickly as possible, the moisture content of the herbage from 70-80% to about 13%, making it safe for storage, which means that organic matter degradation due to bacteria, fungi and enzymes does no longer occur. A rapid drying reduces losses due to respiration processes (oxidization of plant sugars, degradation of protein into amino-acids) and decreases the risk of leaching losses due to wetting of the crop by rainfall. Plant respiration is almost stopped for water content of 30% or less. Rain induces quality losses in four ways: 1) leaching of soluble carbohydrates, vitamins and minerals, 2) increased and prolonged plant respiration, 3) leaf shattering, and 4) microbial breakdown of plant tissue. Typical losses in several nutrients in rained on hay can reach about 10%.

Drying takes places, at least partly, on the field by the action of sun radiation and wind. Low relative air humidity, combined with high temperatures and moderate breezes are favourable conditions for drying. Water losses are initially rapid, especially from leaf tissues. With increasing dry matter contents, remaining water is more and more tightly bound to plant tissues (especially in stems). After leaf wilting, the stomata close and water flow from stems to leaves is interrupted. Leafy species, and in general forbs and legumes, have on average higher water content than grasses and require longer drying times. Equipping mowers with conditioners, causing abrasion, bruising or crushing of plant tissues by a mechanical action immediately after mowing, speeds up wilting. Following the cut, a curing phase takes place in the field. The crop should be first tedded (once) and turned (twice) on the first day, then all further operations should be performed very carefully (low round per minute of rotating implements) to reduce crumbling losses, to which risk the leaves are particularly exposed. Crumbling losses can play a pivotal role in determining the final forage quality, as leaves represent the most valuable plant parts. Crumbling losses increase with increasing dry matter content of the herbage being tedded, turned or swathed and with its leaf-to-stem ratio. Swathing is usually performed just before collecting the herbage to be transported to the barn, but it may also be advisable if there is a risk for the herbage of being wetted. This applies to rainfall events, but also to the overnight dew, which is likely to occur in autumn. If crumbling losses are not a pivotal issue and stable weather is foreseen, a less labour-intensive strategy can be used, e.g. tedding once on the first day (if there is no conditioner), then tedding or turning 48 hours after cutting and swathing after 72 hours before baling on the 4th day.

When weather conditions are not favourable, it is preferable to conserve forage as haylage, rather than risking producing low quality hay.

Legumes and legume/grass mixtures must be wilted more carefully than pure grass hay. Leaf losses can indeed be much more important in alfalfa and red clover based swards compared to grasses. Hay must be tedded at lower speed and early in the morning when dew makes the forage leaves supple. Later in the day, forage leaves are too dry and breakable, which can induce important losses and thus nutritive quality reduction.

Some species are better adapted to hay making than others. In grasses, cocksfoot, tall fescue or timothy can be dried more easily than ryegrasses. In legumes, lucerne can be wilted more easily than red clover.

Effect of topography

Depending on slope, different machineries can be used for harvesting, curing and collection operations. Up to a slope of about 40 to 50%, harvest operations can be fully mechanised (i.e. for mowing tractor-mounted disc mower and specialised two-axle mowers can be used), but beyond such slopes, implements requiring more and more human labour are required (bar mower or even manual mowing by means of scythe). This results in higher costs for both labour and machineries, almost doubling from flat on slightly sloped areas to the very steep ones with slopes beyond 60% (Figure 3.3).

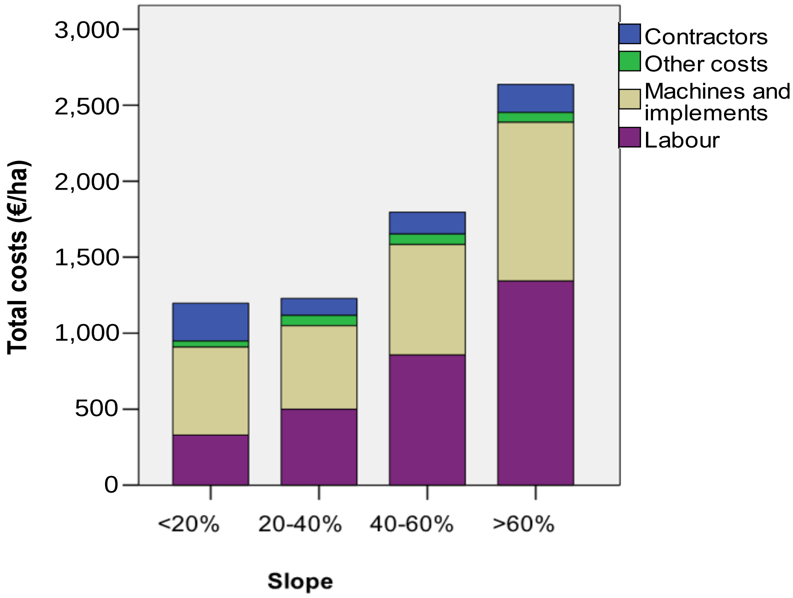


Figure 3.3. Production costs of forage depending on slope (Peratoner *et al*., 2015, modified).

Methods of hay drying

Field drying: The whole drying process takes place in the field. The advantage of this method is the lower requirements in terms of equipment and thus in low capital expenditures. The main disadvantage is the long period of time with good weather for achieving forage stability. Three to five days with favourable weather, depending on the harvested material, on the specific weather conditions and the latitude in Europe, are usually required to achieve a safe state. This results in a high risk in case of periods with unpredictable weather. In case of unusually frequent rainfall, the choice of a suitable harvest time may become very tricky and particular attention to weather forecasts must be paid. In mountain regions, in which orographic rainfalls cannot be accurately forecasted, the prediction of a four-day harvest window can't be given for granted. Moreover, the achievement of the safe state requires a higher number of curing operations at increasing dry matter contents of the herbage, resulting in a high risk of crumbling losses.

Barn drying: Herbage is dried down to a moisture content of 25 to 40% (depending on the performance of the drying facility) and then further dried and brought to safe state in the barn. Several solutions are available to provide air movement and/or increase air temperature or even to decrease relative air humidity and thus to increase the drying efficiency (roof collectors, photovoltaic energy, dehumidifiers). The main advantage of this method resides in the shorter time (one to two days) needed for the field phase, and therefore in the lower risk due to weather unpredictability. Moreover, the reduced need for curing operations in the field of herbage with high dry matter content leads to a reduction of the risk of crumbling losses. The main disadvantage consists in the capital investitures needed for the drying facility and the crane, which is needed to efficiently move the forage to be dried within the barn. Adequate capacity for average yield is needed.

3.2 Silage

Alain Peeters (RHEA Research Centre) and Riccardo Negrini (Associazione Italiana Allevatori)

Silage has been very much developed in Europe in the 1960s as an alternative to hay for better conserving quality forages, especially in rainy climates.

Silage can be made with younger forage than hay and thus with better quality forage. Grass is cut and wilted in the same way than for hay but for a shorter period. Consequently, the harvesting process is less dependent on weather condition. Silage is usually prepared after a short wilting period of one or two days, bringing grass dry matter content from about 20 to ideally about 25-30%.

Silage-making optimum cutting stage is intermediate between optimum grazing and hay-making stages. In spring, it corresponds to stem elongation stage. Vegetative grass can be ensiled too. A compromise has to be found between forage quality and costs per tonne of DM harvested. Early cuts are of high quality but cost more per tonne harvested than later cuts. Weather remains also a constraint. When the ideal cutting stage is approaching, the cut has to be taken when weather conditions are favourable.

Silage-making is an anaerobic process. Forage is compressed for eliminating oxygen as much as possible. This can be done in different silage devices.

After the wilting process, grass can be collected by self-loading wagons and transported loose and stored on a concrete floor surrounded by concrete walls, the entrance of this structure remaining open on one or two sides for loading grass. Tractors are running on the green forage after each layer deposition for compacting it. Finally, when the bunker is full, silage is covered by a plastic sheath for preventing oxygen to come back in silage and for protecting it from rainfall and solar radiation.

The ensiling process (Figure 3.4) is then starting. Six phases can be distinguished.

Phase 1

Aerobic microorganisms present on grass leaf surface consume the oxygen of forage mass creating the desirable anaerobic conditions. Unfortunately, aerobic respiration also consumes water-soluble carbohydrates needed by the beneficial lactic acid bacteria in a later step. All the oxygen is eventually consumed. This process generates temperature increase, carbon dioxide emission and thus nutrient losses, and water evaporation. In good condition, this phase lasts only a few hours.

Phase 2

In the beginning of this phase, oxygen is depleted. Anaerobic bacteria replace aerobic bacteria. The primary bacteria are *Enterobacteria*. They can tolerate heat and can thrive in a pH ranging from 7 to 5. These hetero-fermenters produce both acetic (a weak acid) and lactic (a strong acid) acids. The final proportions of these acids depend on grass maturity, moisture, and the composition of spontaneous bacteria communities. This phase usually lasts 24 to 72 hours.

Phase 3

When the pH is lower than 5, homo-fermenter bacteria take over. These bacteria are more efficient than hetero-fermenters. They produce lactic acid. Lactic acid is the most desirable of the anaerobic fermentation acids. Silage pH quickly decreases. As the temperature of the silage mass decreases and the pH continues to drop, bacteria are inhibited. Phase 3 is a short and transitional phase. It usually lasts only 24 hours.

Phase 4

Homo-fermentative bacteria continue converting water-soluble carbohydrates to lactic acid. Temperature stabilizes. In well-preserved silage, lactic acid should represent more than 60% of the total silage organic acids. This lactic acid phase is the longest of the ensiling process. It continues until the pH is so low that all bacteria are killed. Fermentation is then stopped and consequently forage can be conserved for a long period. The final pH depends on the type of forage and the dry matter content of the ensiled forage. It can range from 4 to 4.5.

These four first phases can be completed within 10 days to 3 weeks from harvest. It is thus recommended to wait at least 3 weeks before feeding freshly prepared silages.

Phase 5

The fermentation process is stopped. Some changes do occur. Starch becomes more quickly degraded in the rumen with longer storage times. Some changes may also occur in the digestibility of the neutral detergent fibre (NDF).

Phase 6

When feed out begins, oxygen is introduced in the silo. This can lead to substantial dry matter losses. Proper management of the silage face can minimize losses.

The grass silage process described above is similar to the ones that occur in the preparation of ‘sauerkraut’ (fermented cabbage recipe) or gherkins pickled in brine.

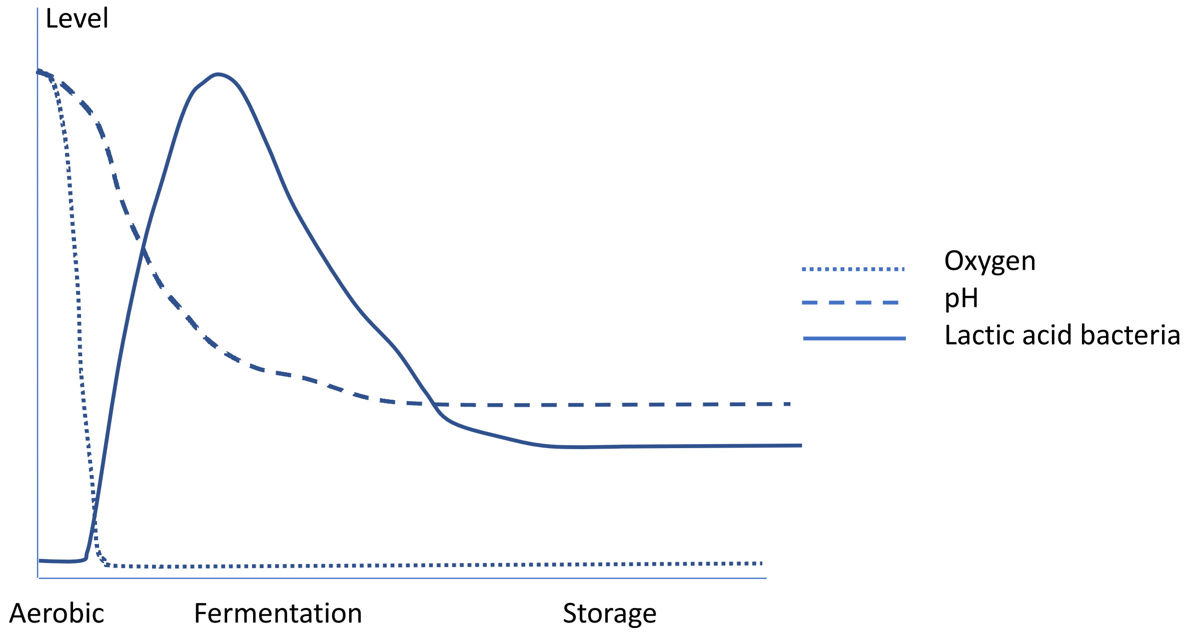


Figure 3.4. Oxygen, pH and lactic acid bacteria population evolution over time in a favourable ensiling process (after Dunière *et al.*, 2013).

Other ways of conserving silage than bunker silo, are possible. The fermentation process is the same.

Self-loading wagons can deliver harvested forage at the basis of a silage tower. Then, a blower brings wilted forage through a pipe at the top of the tower and injects it inside. Compaction occurs naturally by the effect of forage weight. Forage material at the bottom of the tower should be ensiled at a high DM (35 to 40%) to prevent effluent release. The upper surface of the silo is not compacted, it is exposed to air. Consequently, aerobic fermentation can occur on the first meter, leading to forage losses.

A simple silo can be prepared on the ground, in a field. It is compressed by tractors and covered by a plastic sheath. This type of silage heap is cheap, but it can be contaminated by earth and the compaction work is dangerous because the tractor can turn over while running on heap sloping side.

Wilted forage can be harvested and compressed by round or square balers. Bales are then packed in plastic sheaths. This system is more expensive than the two first ones, but it brings flexibility in the silage-making process. Small plots or plot sections can more easily be harvested because this system does not require to open a large silage bunker which could lead to silage degradation. Silage bales are also easy to distribute to livestock in barns or outdoors. Round bales can for instance easily roll on the ground which facilitates forage distribution. Bales should be checked regularly because crows and rodents can create holes in the plastic through which air can penetrate and induce forage quality degradation. Punctures should be quickly fixed. Bales should be stored on a compacted or stony floor for preventing rodents to make galleries underneath. Hedge bases are particularly unsuitable locations for storage.

Forage species effect

Legumes, e.g. alfalfa and red clover, have lower water-soluble carbohydrate contents and a higher buffering capacity than grasses, especially perennial ryegrass. The final pH of legume silos is thus slightly higher than grasses. Nevertheless, it is totally possible to make good legume or grass/legume mixture silage when good practices are adopted.

Undesirable fermentations

If forage is contaminated by soil, dry matter content is too low and pH is not low enough for stabilizing silage, then other anaerobic bacteria (*Clostridia*) induce butyric fermentation (Figure 3.5). They transform lactic acid into acetic and butyric acids, and protein into ammonia. This reduces silage intake by ruminants.

If prevention measures for harvesting a clean forage and reaching an optimum DM and water-soluble carbohydrate content are not sufficient, additives can be used. These additives are added in the silo. They can be formic or sulphuric acids, bacterial inoculants or soluble sugars such as molasses.

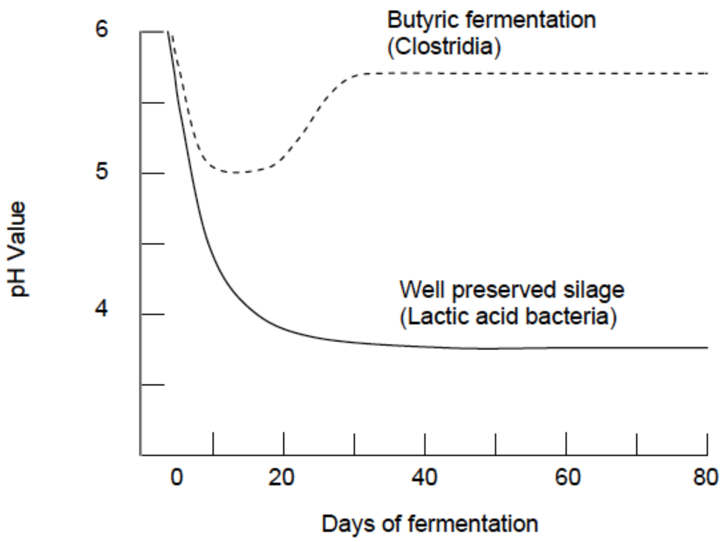


Figure 3.5. Changes in pH during silage preservation for butyric and lactic acid production. (Knabe *et al*., 1986 in DairyNZ)

Loss prevention measures

There are a number of measures to be taken for limiting losses during harvesting and fermentation:

- Grass should be ideally cut after one or two sunny days for increasing water-soluble carbohydrate (sugar) content. It can then be cut in the morning of the next

sunny day. In less favourable weather conditions the days before, it should be cut in the beginning of the afternoon of a sunny day.
- Wilting grass should be done as quickly as possible for limiting sugar losses. If possible, it should be done in no more than 24 hours.
- In bunker silo, silage should be well compacted with a heavy vehicle. For baled silage, a high-density baler should be used.
- The stack should be completely covered with a heavy, airtight cover. This cover sheath should be first washed if not clean enough.
- A covered stack should not be reopened for adding more forage later on.

Measures can be taken to limit losses during feeding out. When silage is exposed to air again, aerobic microorganisms can start using oxygen for digesting silage nutrients. This induces a temperature increase and nutrient degradation. Losses can be limited by the following means:
- The exposure of silage to air face should be limited to a minimum. This could be achieved by removing a piece of at least 20 cm deep each day on the front face.
- Feeding out should thus be done every day, especially in summer.
- The stack face should be kept open on warm days to avoid heat under the cover sheath.
- Cutting silage off the face, rather than pulling it off. This keeps a smooth surface at the stack face, which reduces air penetration into the stack.

Silage quality can be checked by traditional nutrient value analysis and by specific fermentation quality analysis. This last analysis includes:
- Ammonia nitrogen (NH_3-N) in % of crude protein (CP): proportion of N broken down during ensilage.
- Total fermentation acids (TFA): total amount of acid produced during fermentation. It includes lactic, butyric and acetic acids and possibly also propionic acid and ethanol.
- Volatile fatty acids (VFA): VFA is high when fermentation is poor.
- Lactic acid: typical lactic acid contents range from 60 to 150 g/kg, higher values are better. A proportion of lactic acid in the total fermentation acids (TFA) > 70% is ideal.
- Acetic acid: high levels can restrict intake.
- Butyric acid: indicates poorly fermented silage.
- Residual sugar (RS): valuable source of energy for rumen microorganisms.
- Ethanol: should be very low, because it is associated with the growth of undesirable yeasts.

Good quality silages are low in butyric and acetic acids, low in ammonia-N, and high in lactic acid and sugar.

3.3 Techniques adapted to legume and legume mixtures

Alain Peeters (RHEA Research Centre) and Riccardo Negrini (Associazione Italiana Allevatori)

Most scientific and technical publications on grassland forage conservation deal with pure grass mixtures and especially pure perennial ryegrass. Publications on legumes are rarer. Those on mixtures are almost inexistent. However, farmers use mainly mixtures.

Mixtures harvested for forage conservation can include grass, legume and other dicotyledon species. Wilting dicotyledons in general requires techniques that are different than those used for grasses. This section focuses on legumes.

Seed mixture and sowing

Lucerne is usually sown in mixture with grass. Cocksfoot is its most frequent companion grass. Lucerne/cocksfoot mixture is better sown from Mid-August to Mid-September. It produces then a normal yield the following year. If sown in spring, it is more likely to be invaded by weeds and the yield is very much reduced. Two cuts can be expected instead of four in a normal year.

Lucerne/grass mixtures have several assets compared to pure lucerne. They cover the soil faster after sowing and can better control weeds. They stabilize yield repartition over time. In cold periods for instance, when lucerne growth is reduced, grass dominates the mixture and ensures a better yield. Mixtures are also easier to wilt and to conserve as hay, haylage or silage.

Cutting time

Typically, in Atlantic climates of North-West Europe, lucerne and lucerne mixtures can be harvested from mid-May onwards. They produce high DM yields without any nitrogen fertilization. Average annual yield often reaches 15 t DM/ha in farm conditions. An example of the proportion of annual yield per cut is shown in Table 3.2.

Table 3.2. The proportion of annual yield per cut in a lucerne plot harvested four times a year.

Cutting number	**Cutting time**	**Proportion of total yield (%)**
1st	Late May	35
2nd	Early July	35
3rd	Mid-August	20
4th	Late October/early November	10

Source: Genever and McConnell, 2014

Other slightly different timing of the four cuts are frequent: mid-May, mid- to end of June, end of July, end of September.

Table 3.3 presents average yield repartition collected in a farm network in the Centre East of France. These regions are drier compared to the regions of Table 3.2. Average yields reach 9 t DM/ha only. In continental climates, yields of about 12 to 13 t DM/ha seem to be more typical.

Table 3.3. Yield repartition of lucerne (t DM/ha) in the three first cuts in the Centre East of France (Drôme, Isère, Rhône and Loire).

	1st cut	2nd cut	3rd cut
Average 1985-1987 (t DM/ha)	4.0	2.6	1.6
% yield of each cut in total production	49	32	19

Average yield of the 4th cut: 1 t DM/ha. Results of a network of 43 farms (190 plots - 139 ha) (1984-1987) (Mauries, 1988).

Lucerne is cut at pre-bud stage because it is the best compromise between yield and quality, but it has to be harvested at least once a year at full bloom for increasing the lifespan of the crop (Figure 3.6). At pre-bud stage, flower buds can be felt under fingers by grasping the end of a stem. On 20 stems picked at random, four should have flower buds. Figure 3.7 shows that root nutrient storage is only reconstituted at flowering stage.

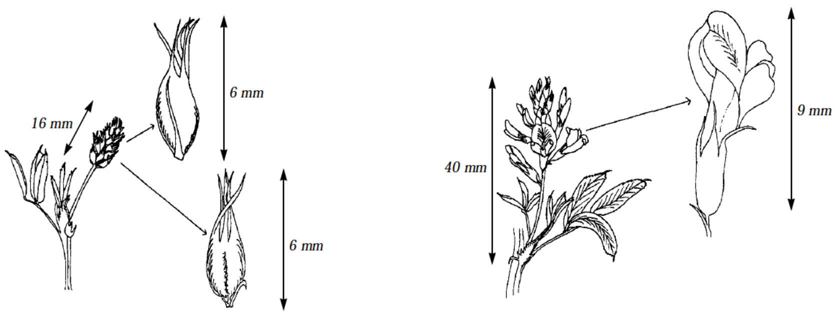


Figure 3.6. Bud (left) and full bloom (right) stages of lucerne.

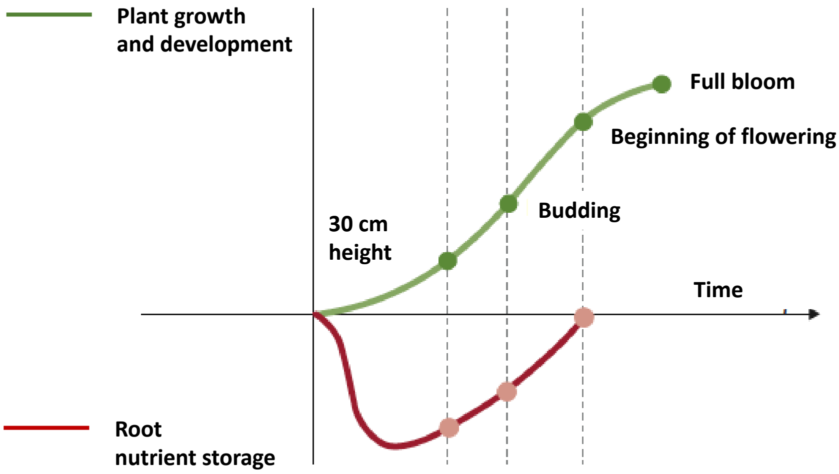


Figure 3.7. Evolution of physiological stages and root nutrient storage during an uninterrupted growth period of lucerne (Demarly in Delisle, 2010).

The last growth can be grazed for prolonging the grazing period. This should be done by strip grazing with one-day occupation. Grazing is more interesting than harvesting the small available production at that time of the year.

Mowing and wilting

Cutting height is very important for persistence and total annual yield. Cutting too short reduces yield and persistency because plants have to mobilize too much nutrient resources from their roots and crown for rebuilding their leaf area after a cut.

The height of new stems is a good indicator for deciding the best cutting time. New shoots should be visible but short enough to avoid cutting them with the mower (Figure 3.8).

Lucerne is almost always cut too short in practice. The minimum cutting height is 7cm to avoid damaging the crown of the plant. This cutting height has also two other advantages. Cut forage is deposited on these relatively long stems which create a space between ground and forage where an airflow can circulate which helps wilting the green mass. This cutting height reduces also earth contamination risk.

Lucerne leaves can contain up to 70% of the protein and 90% of the minerals and vitamins of the aerial parts of the plant. Lucerne and other legumes such as red clover, are difficult to wilt because leaves, the most nutritious part of the plant, can easily detach from the stem and fall down onto the soil if wilting is too aggressive. As wilting progresses this risk increases (figure 3.9). It is very high at the last passage of the mower for hay making. The mower should run slowly, and mowing and raking the crop should be done in the morning dew just after sun rise. At that time, leaves are suppler. Tedders are indeed responsible of most losses, windrowers produce only about 3 to 5% of total losses.

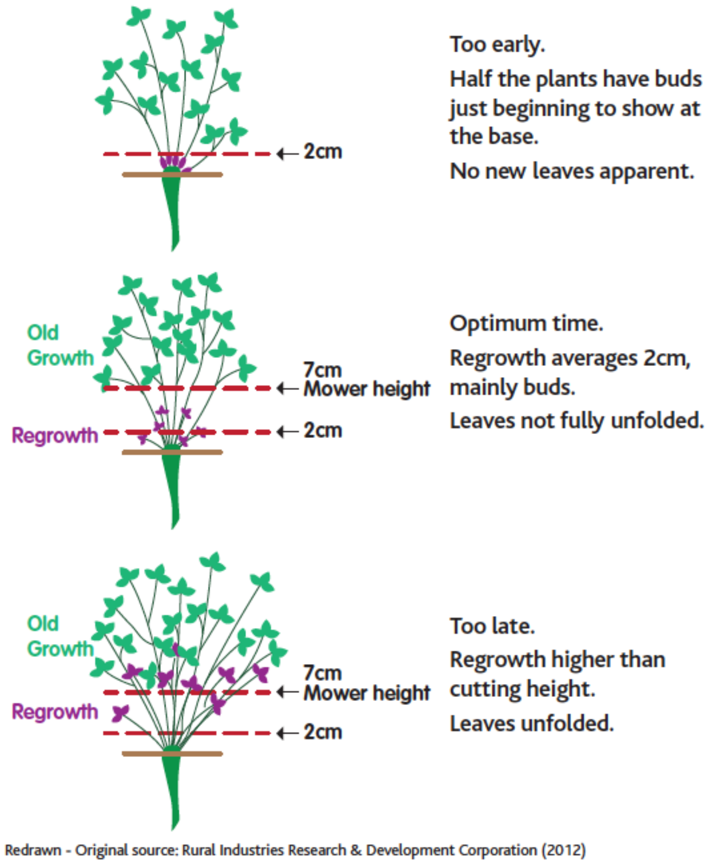


Figure 3.8. Determination of optimum cutting time of lucerne (Genever & McConnell 2014).

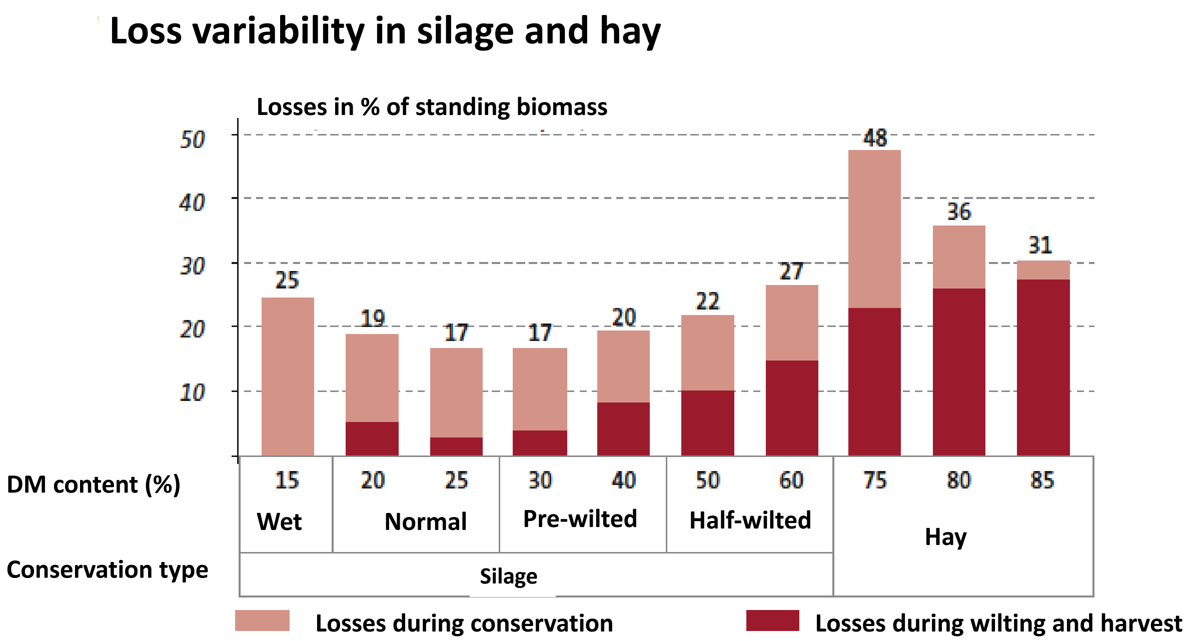


Figure 3.9. Losses at harvest and during conservation according to intensity of wilting and conservation type (Credit: Arvalis – Institut du Végétal in Delisle 2010).

Lucerne/grass mixtures are easier to wilt because lucerne leaves and stems are diluted in a mass and protected by a weft of more flexible grass leaves. They are also easier to ensile due to the higher sugar content of grasses.

Roller-type mower conditioners can speed up the rate of moisture loss from the stem, but they can also increase leaf shatter. If adopted, they should be used with great care. Their cost is also a limiting factor for their use. The lucerne area should be big enough for paying back the purchase of this equipment.

Ensiling process

Lucerne silage can be preserved either in bunker silo or in big bales. Target DM content should be 30–40% for bunker silage and 50% for big bale silage.

Lucerne stubble can pierce the wrap of silage bales. This should be prevented by using at least four layers of plastic. After moving bales from the field to the storage place, they should be checked for damage and, if needed, repaired.

Legume species

All the information described for lucerne is also valid for red clover, athough red clover is more often mixed with ryegrasses, meadow fescue and timothy. Red clover/cocksfoot is a very good mixture too.

Red clover stems dry out more slowly than lucerne stems. This is not a problem for silage-making, but it is for hay-making. Red clover is thus better adapted to silage.

Nutritional characteristics

Lucerne and red clover have outstanding nutritional characteristics. Protein and calcium contents of red clover and lucerne are high. Forages of both species are highly digestible.

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4. Soil and nutrient management

The potential productivity of grasslands, like that of crops, depends primarily on climatic and soil factors. Soil and nutrient management can then increase (or reduce) this potential.

4.1 Soil characteristics related to grassland

Julien Fradin (IDELE), Benoît Delaite (TR@ME), Xavier Delmon (TR@ME)

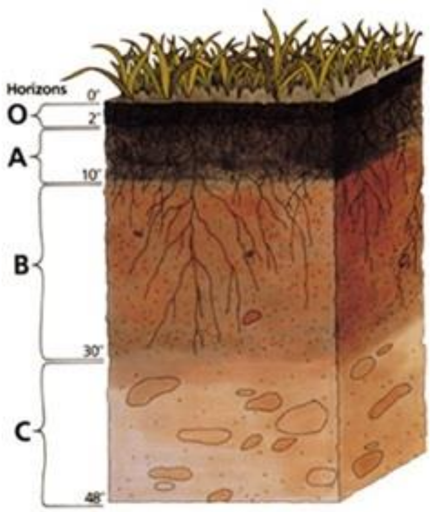
Soil is an essential resource (FAO, 2015) that is important to understand and use according to its specificities. This is essential when looking at grassland production and ecosystem services provided by grasslands. The complexity of the soil lies in the fact that all its compartments are at first hidden.

<u>What is soil?</u>

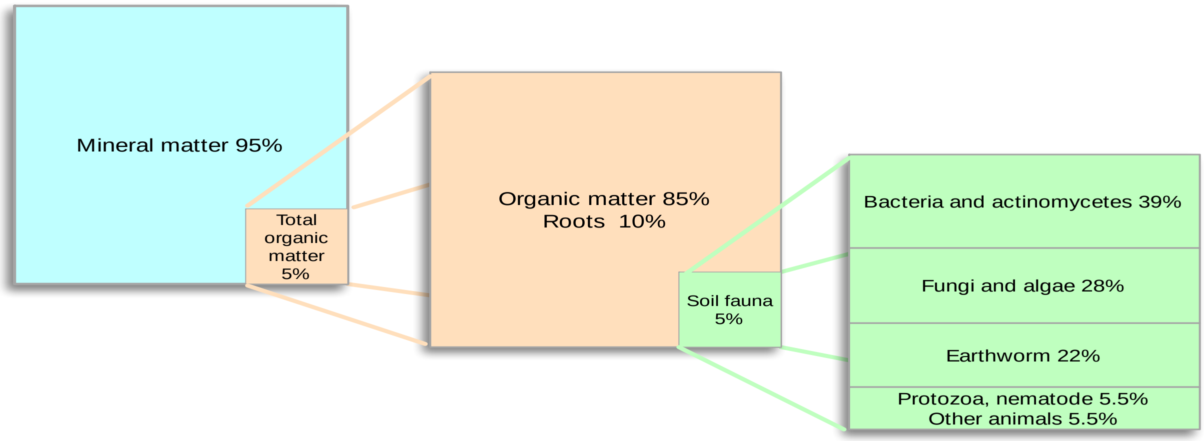
Soil is an environment that is constantly evolving as a result of processes of alteration of the parent rock and transformation by organic matter. One interest is only in the part of the soil potentially colonized by the roots of plants. It is generally accepted that 1 cm of soil needs a century to form.

<u>The composition of the soil</u>

A soil consists of vacuum, 40% to 60% depending on its degree of compaction, it is the porosity of the soil. It defines the volume of soil likely to be occupied by living beings, roots, air or water. The solid part of the soil is mainly of mineral matter for about 95% of mass, except soil of peat. The rest is represented by organic matter, alive and dead. Although it is little in terms of mass and is only concentrated in the first 20 centimetres of grassland soil, organic matter plays a key role in its functioning. Indeed, soils contain the largest stock of organic carbon in the continental biosphere. The properties of organic matter are strongly implicated in the environmental and agronomic problems affecting soils.



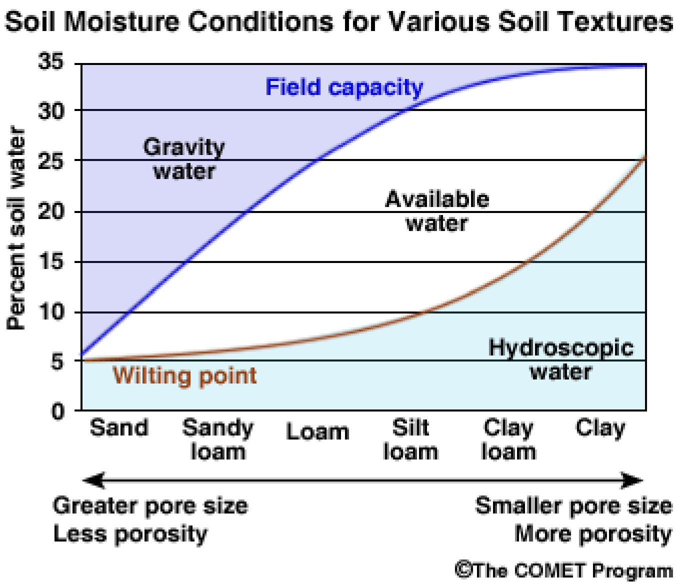
O : organic horizon where decaying matter acumulates
A: topsoil or surface horizon, mixture of organic matter and minerals, highly fertile where most of soil life occurs
B: Subsoil, little organic matter and accumulation of weathered materials (clay and oxides minerals)
C: Substratum or parent material, layer little affected by weathering process
Figure: composition of the soil. Source: NRCS - USDA



Topsoil layer components within temperate grassland (Bachelier, 1978)

Nature and size of soil components

The parent rock determines some of the properties of the soil, including its physicochemical components. Soil particles are classified by size. From the biggest to the smallest, there is sand, silt and finally clay. The relative proportion of these types of materials determines the texture of the soil which gives a good idea of the general behaviour of the soil. Sand gives excellent drainage, the bearing capacity is good and allows to farm grassland longer in the season, in return they dry much faster than other types of soil.



The soil capacity to store water is directly related to its texture, characteristics inherited from geological events on which the farmer has no influence. The rougher the particles, the more drainage capacity and the less water content. With the increase in soil organic matter content, generally high under grassland, the amount of water stored increases significantly. The organic material acts as a sponge and can store up to 20 times its weight in water. But water stored in soil does not exactly match the water available to plants because it is too strongly bound to particles. Clay soils retain water more strongly than any other type of soil, preventing partly its use by plants. The loamy soils have the best capacity to store and supply water for the crop.

Soil structure and physical fertility

The arrangement of soil particles, minerals and organic matter forms "aggregates" of various sizes. Their juxtaposition confers the structure upon the soil. A good structure allows the penetration of roots and water while maintaining a good soil cohesion. Soil tillage brings air within soil which makes rooting easier but reduces soil structure stability. Aggregates avoid water and wind erosion as well as reducing soil compaction. A strong biological activity allows the formation of a crumbly structure favourable to the flow of air and water. Earthworms are the animals most involved in the formation of aggregates because they blend tons of soil in the case of grasslands. The soil structure stability increases with the organic carbon content.

Soil Fertility: Soil fertility is a concept that evolves over time and many definitions coexist. According to Abbott and Murphy (2003), soil fertility is its ability to provide the physical, chemical and biological conditions necessary for the proper development of cultivated plants. The concept of soil fertility can vary depending on the crop. Today organic matter is considered as pillar of soil fertility.

Soil chemical fertility

The mineralogical clays have the ability to exchange cations (Ca^{2+}, K^{+}, Mg^{2+}, Na^{+}) thanks to their structure in the form of superimposed layers which are negatively charged. There are different types of clays that store more or less mineral elements; the more the clays have the capacity to swell, the more they offer great reserve of minerals. Likewise, the finer the particles, the higher is theoretically soil fertility because the exchange surfaces between the soil solution, the biological activity and the nutritive minerals are increased. The mineral elements of the soil can also be adsorbed by metal oxides (iron, aluminium) and organic matter. Soil organic matter is also the element with the greatest capacity to store and provide elements by its sponge-shaped structure. In the case of a soil with a low cation exchange capacity, that is to say a low reserve of mineral elements, it is advisable to bring mineral inputs in small quantities but more often.

Minerals need a correct pH to be assimilated by plants. For good soil functioning, it is best to have a soil pH between (between 6.2-6.7 is even better). The H^{+} protons are naturally released by plant roots and biological activity, which acidifies the soil. The biological activity of soils is favoured with a slightly acidic pH around 6.5. The organic matter in the soil has the capacity to fix the protons to a certain level, the addition of carbonate via liming supplements this action.

Biological fertility

Soil is a biological medium to the extent that it allows the development of living organisms. Within grassland soils are the largest communities of macroscopic fauna; up to 6 or 7 tons of organisms live in grassland soils.

These living organisms and decaying organic matter are a reservoir of nutrients. Biological activity is largely responsible for the mineralization of organic matter. The size of the particles of organic matter determines the type of fauna capable to degrade them by the enzymes they produce. Thus the diversity of soil and micro-organisms is essential for the good transformation of plant, animal and microbial material. The lower the C / N ratio of organic matter, the faster their mineralization. Because of their constitution, plant residues, especially roots, have the longest life in soils. On a soil analysis, the C / N ratio of the organic matter must be less than 10-12, beyond the organic matter is not degraded by lack of available nitrogen.

There are two main types of organic matter, labile organic matter and stable organic matter. The labile organic matter is less than 10 years old and consists of large residuals of 50 µm to 2 mm decaying. It is the major source of energy for soil micro-organisms. By its development the soil fauna also provides the nutrients needed by plants. The more labile organic matter, the more biological activity and the more constituents are available for plant growth. On the contrary, the stable organic matter, also called humus, is on average 50 years old. It is not accessible by micro-organisms because it is protected by physical or chemical barriers. Very fine, fixed to clays, it ensures the physical stability of the soil.

Grasslands are the richest environments in organic matter. Given the prominence of organic matter for soil quality, it is essential to foster them by avoiding ploughing of meadows too regularly and by having an integrated management of irrigation and fertilization.

4.2 Main macro-nutrients: N P K

Julien Fradin (IDELE), Benoît Delaite (TR@ME), Xavier Delmon (TR@ME)

As we have seen above, the availability of mineral elements within the soil will influence the productivity of the grasslands. The limiting factor is usually a macro-nutrient, most commonly nitrogen, but soil and pH analysis should be used to determine this limiting factor.

<u>Integrated fertilization:</u>

Integrated fertilization relies on three combined approaches:

1. Assess the elements exported and those available in the soil to calculate the elements to be brought.
2. Calculate the elements available in the soil: related to organic matter mineralization and microbial fixation, particularly through legumes.
3. Make a balance between marginal productivity gains and marginal fertilization costs: it is economically useless to try to produce the maximum.

Nitrogen fertilization

Nitrogen is the essential element to monitor, the inputs are controlled because of the risks of leaching. European legislation has established spreading standards depending on the form (mineral or organic), seasons, climate and slope.

Reminder of grassland N regulation: max 350 kg of total nitrogen/ha/year, of which max 170 kg of nitrogen of organic origin (including restitution by dung). This general regulation has been amended in several countries or regions (going to a maximum of 250 kg/ha (Ireland, parts of the Netherlands) or 230 kg/ha (Belgium, Austria, Denmark, Germany, parts of the Netherlands…). Special situations (watercourse, relief, soil type) may require lower levels.

Nitrogen exports depend on the type of grassland utilisation (grazing, hay making, silage making). A strong relationship exists between the organic matter content of the soil and the amount of nitrogen released by its mineralization. This relationship is influenced by climate and soil. Beyond a certain threshold, there is no longer any relationship between the content and the supply of nitrogen. Manure patches in pasture meadows provide nitrogen as well. In Belgium, for example, it is considered that 100 LU per ha per day return the equivalent of 9 kg N per ha.

Fertilization will bring nutrients to the soil. Macro- (and micro-) nutrients must first be returned by manure (taking into account legislation). Mineral fertilizers are only used as potential supplements. To calculate the inputs of farm manure, account must be taken of:

- the contents of elements in manure or slurry
- the actual fertilizer value of the element, that is, the quantity that will be released during the mineralization along the year. This is expressed by a coefficient of equivalence with respect to mineral fertilizers.

For these calculations, different countries have tables that express the content of elements in different farm fertilizers, as well as their equivalence coefficient compared to mineral fertilizers. Equivalence coefficients take into account that organic molecules do not release fertilizers so quickly than synthetic molecules. On the other hand, organic fertilisers contribute much more to the organic matter content of the soil.

Ten rules for the proper application of farm manure (Agraost, Belgium)

1. Know the fertilizer value of farm manures
2. Homogenize the product (mixing or dilution of manure, composting of manure).
3. Ensure the quality of the distribution of the product behind the spreader: check the spreaders and slurry drums, check the spread quantities. They must not exceed 15 m^3 of slurry or 30 to 40 tonnes of cattle manure per pass. Thoroughly crumble the manure in order to limit the risk of smearing the harvested forage and the development of butyric bacteria in the silage, as well as the appearance of voids in the grass, gaps which will facilitate the germination of weed seeds.
4. Favor the climatic conditions suitable to the realization of the spreading: rainy or covered weather, little wind and low temperatures.

5. Work on bearing soil and short grass.
6. Respect the needs of meadows.
7. Spread during periods of optimum recovery, respecting the agriculture good practices (nitrogen management plan), and limiting environmental risks. In general, the best period is from February to April depending on the region.
8. In pasture meadows, avoid soiling the grass. For this avoid the use of fresh manure that leads to a reduction in palatability and therefore to a bad use of the grass with the appearance of refusal areas. In addition, manure can promote the dispersal of certain pathogenic germs (Salmonella, Botula). These problems will be avoided by the use of compost or digestate or manure, making sure to work with systems of injection in the ground (drip hose spreading boom).
9. Limit volatilization losses when spreading slurry by working as close to soil as possible or by injecting into soil.
10. Respect the neighbourhood.

Nitrogen Efficiency Coefficient for Complement Calculations

To finalize the calculation of the supplement to be provided in the form of synthetic fertilizer, we start from the exported quantity * from which we deduce the contributions of the soil *, the restitutions in pasture (dung), the contributions of the leguminous and the contributions of farm fertilizer (manure).

The quantities marked with * are reduced by a coefficient of efficiency which takes into account that some of the nitrogen is not directly used for the production of fodder and goes into the soil, water, air or non-exported organic materials. This factor is usually between 0.7 (France) and 0.8 (Belgium).

Additional mineral fertilizer needed = Exported item / Eff. coeff. - [Soil release / Eff. coeff.; Restitution during pasture (dung); Contribution from legumes; Supply from farm manures X Coeff. of equivalence]

Supply of phosphorus and potassium

The same reasoning as for nitrogen applies to phosphorus and potassium. The ideal is to start from a soil analysis. The needs will be all the higher as the use of the grassland will be intensive.

In general, fertilizer inputs by farm manure (slurry, manure, compost manure) are sufficient and should not be offset by mineral fertilizers. Quantities can be estimated based on national farm fertilizer composition tables, taking into account, as for nitrogen, an equivalence coefficient that takes into account the mineral fraction not used by plants.

4.3 Biological nitrogen fixation

Julien Fradin (IDELE), Benoît Delaite (TR@ME), Xavier Delmon (TR@ME)

Among the macro-nutrients, nitrogen is special because it can be provided by legumes that fix nitrogen from the air through symbiotic bacteria that live in nodules attached to their roots. This nitrogen is then available for the legume, but also nearby plants.

In Belgium, comparative trials over 5 years have shown that, on average, an English ryegrass association with red clover has a higher energy production and total nitrogen content than English ryegrass alone, even fertilized with 400 units of nitrogen (Fourrages Mieux, 2008).

In addition to nitrogen fertilizer reduction, the grass-legume combination offers many other benefits (Fourrages Mieux, Belgium) :

- Maintaining a dense and closed grass cover;
- More stable production, especially in summer;
- Better staggering of production periods;
- Better palatability;
- Better quality of fodder;
- A good balance between mineral elements;
- Better soil use through different root systems;
- Forage quality that is maintained over time thanks to legumes.

The main disadvantages of associations are :

- More difficult control of harmful weeds;
- Difficult management of the proportion of legumes in the association;
- Risk of losses during haymaking that may be greater (loss of legume leaves).

Nitrogen intake according to the proportion of legumes

The proportion of legumes and the productivity of the grassland must be taken into account to adapt nitrogen input (Source: GREN Bretagne, 2017). This nitrogen intake should be capped at the amount actually used by the plants over a growing season. It depends on the duration of growth and partially on the type of soil, and therefore on productivity. In France, a maximum of 50 kg of effective nitrogen per hectare is generally taken into account.

Depending on the share of legumes in the association (in %, estimated in the spring) and the productivity of the grassland (in t DM / ha), the nitrogen supply varies from 0 to 100%.

- Below 10% (visually grasses dominate largely), the contribution of legumes is negligible.
- Between 10 and 30% of cover (visually, the grass is dominant, but legumes are apparent), legumes will provide on average between 40 to 95% (white clover) and 30 to 75% (other legumes) needs in nitrogen the grassland. This contribution increases steadily according to the productivity of the grassland (from 5 to 12 t DM / ha). See table below as an example for Brittany.

Production of the meadow (t DM /ha)	Share of 10 to 30% of legumes
5	40%* - 30%
6	50%* – 40%
7	55%* – 45%
8	65%* – 50%
9	70%* – 55%
10	80%* – 60%
11	87%* – 67%
12	95%* – 75%

Source : GREN Bretagne, 2017

- Over 30% of legumes (visually, one sees almost everywhere), the nitrogen supplied covers all the nitrogen needs of the grassland.

Remark

A more detailed analysis is recommended to calculate the amount of nitrogen to bring. It depends on the balance between the exported nitrogen (which is a function of productivity and the maturity stage of the crops) and the nitrogen supplied by the soil (residue of previous crops) and legumes.

Tables or online calculation aids are available in the different European countries, e.g.

- Belgium : https://protecteau.be/fr/nitrate/agriculteurs/fertilisation-raisonnee/ferti-prairie (to be used with Firefox)
- France : http://draaf.bretagne.agriculture.gouv.fr/IMG/pdf/GREN_annexe8-1_prairies_09_03_2017_cle874215.pdf
- Ireland : https://www.fertilizer-assoc.ie/p-k-calculator/calculator/
- The Netherlands : www.bemestingsadvies.nl
- UK : https://www2.dardni.gov.uk/gatewayweb/internet/

When to bring nitrogen to a grass-legume association?

a. When installing the meadow in association. To support the start-up of legumes not yet provided with nodules, fertilize with half the effective nitrogen dose (20-25 kg of nitrogen).

b. For the meadows installed: The amount of nitrogen to be supplied is calculated to supplement the nitrogen of microbial origin (see previous paragraph).

At the end of winter: boost the meadow with mineral nitrogen to maximize the spring shoot, even in the presence of up to 40% legumes. In fact, legumes (and their bacteria) enter in growth after grasses. So during this time, grass cannot take advantage of the nitrogen of bacterial origin. The precise moment to bring this fertilizer can be calculated by the rule of cumulative 200 ° C x days. It is also necessary to take into account the periods of prohibition of spreading. The quantity brought depends on the vegetation and the type of soil (30 to 50 nitrogen units).

Calculation of cumulative 200 ° C x days:

Record daily minimum and maximum temperatures under shelter,

Make the daily average: (T min + T max) / 2,

Cumulate daily averages above 0 ° C.

The optimum moment for the first mineral nitrogen application is a cumulative sum of 200 ° C x days.

Source : https://www.arvalis-infos.fr/azote-mineral-et-prairies-appliquer-la-regle-des-200-cumules-@/view-14015-arvarticle.html

How to install a grass-legume association

The temperature requirements of legumes during installation are higher than grasses. The optimal sowing period is therefore late summer or spring.

Seeding in combination is to be carefully prepared because the corrections are very difficult: the combined presence of grasses and legumes greatly reduces the options for chemical weed control.

- Prepare a very fine seedbed, on clean, packed soil (croskill rolls);
- Sow at a depth of 1 cm. (In Belgium, 1,900 seeds / m^2 are recommended.)

- Graze/mow the first cut of the new reseed early to prevent weeds from rising to seed and eliminate annual species.

The choice of varieties to associate depends on:

- The soil and climate (fertility, depth, pH, risk of drought or flood)
- The management issues (biodiversity, erosion, landscape aspects)
- The desired longevity for the meadow
- The mode of exploitation of the future meadow:
    - For mowing, avoid ryegrass and tetraploid clover that dry slowly. Alfalfa, diploid purple clover and white clover are best suited.
    - For grazing, prefer trampling-resistant species such as perennial ryegrass, tall fescue or white clover.

4.4 Liming

Martin Komainda (University of Göttingen), Giovanni Peratoner (Laimburg Research Centre), Nora Schiebenhöfer, Johannes Isselstein (University of Göttingen)

Spreading lime can increase grass production and utilisation. It improves the soil fertility, the water holding capacity, the soil structure, the soil biology, the nutrient status and the pH of the soil. Low soil pH levels may be detrimental for the growth of plants, which is mainly due to the release of aluminium, the immobilization of phosphate, the increased leaching of cations (i.e. Mg and Ca) and a reduced microbial activity. Under some conditions excess pH levels also induce detrimental effects due to iron deficiency (Fig 2) or excess mineralization of organic soils. Limes contain varying amounts of nutrients, of which calcium oxide (CaO) and magnesium oxide (MgO) are the most prominent. Liming is primarily utilized to increase the soil pH and the liming effect of an applied lime is expressed in proportion (%) to the liming effect of CaO. Besides increased pH levels, the CaO improves the soil structure due to its ability to form clay-humus-complexes. Table 4.1 gives an overview on frequently applied limes.

Table 4.1. Forms of applied limes (according to Schilling, 2000 and Schubert, 2006)

Lime	Form	liming effect (% CaO)	minor components
Limestone	$CaCO_3$	42-53	silicate
limestone with Mg	$CaCO_3$, $MgCO_3$	42-53	silicate
burnt lime	CaO	65-95	MgO
slaked lime	$Ca(OH)_2$	60-70	$Mg(OH)_2$

Due to the negative externalities arising from low pH levels and disadvantages of excess pH, the correct determination of the liming demand is of uppermost importance. The possibilities to quantify the demand are exemplified in Figure 4.1.

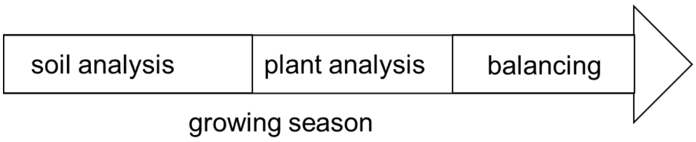


Figure 4.1. Determination of the liming status of respective soils, plants and respective balancing. The analyses should be conducted regularly

Soil samples are taken at depths between 10 and 30 cm prior to any fertilization or liming activity to quantify the actual status of the soil regularly (e.g. in spring). The samples should be kept cool until analysis. Figure 4.2 gives an overview of the scheme for soil sampling. Approximately 20 sampling points per hectare are required at minimum.

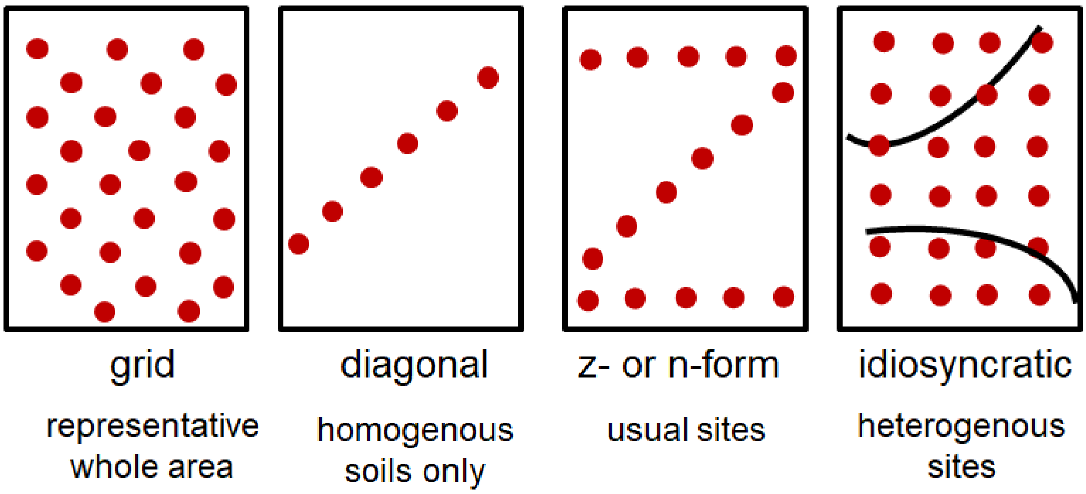


Figure 4.2. Described are several options for a representative soil sampling on a grassland or arable field site. Derived according to Schubert (2006) and Schilling (2000).

Plant analyses are usually taken at harvest on the fresh biomass, in silages or in hay. Every field/pasture should be sampled adequately. Both, soil and plant samples should be analyzed for contents of CaO by accredited laboratories. Farm advisors can help to find appropriate laboratories.

The liming demand, however, is also a function of the clay and the humus content of the soil. Agricultural soils may contain more than 30% humus, whereas typically values between between 5 and <15% are found (organic soils are higher). For intensively managed grasslands, approximately 3 to 4 dt CaO ha^{-1} are taken up annually by the grass sward and exported via harvested products. A general conclusion on the CaO demand is consequently challenging if no samples are taken. Therefore, precise knowledge on the CaO content (soil and or plant) enables exact calculation of the CaO export. In view of a large share of dairy farms located on sandy soils, Table 4.2 highlights the CaO demand for a soil with a humus content ≤ 15%. The presented amounts are required annually to remain in a good soil status. However, to minimize labor, liming in a three-year-period is possible due to low leaching losses.

Table 4.2. Example for liming requirement of grassland on an optimally supplied soil, i.e. optimal pH range. This means only liming of the exported CaO required (Fertilizing guideline of Northern Germany, 2018).

soil texture	pH range	CaO dt ha^{-1} $year^{-1}$
sand	4.7 - 5.2	4
loamy-sand	5.4 - 6.0	5
sandy to silty-loam	5.6 - 6.3	6
clayey	5.7 - 6.5	8

4.5 Use of animal manure

Martin Komainda (University of Göttingen), Giovanni Peratoner (Laimburg Research Centre), Nora Schiebenhöfer, Johannes Isselstein (University of Göttingen)

General considerations

Ruminant livestock producers feed up to 100% grass in the diets and grassland systems for ruminant livestock production are associated with regular export of nutrients within the harvested biomass or animal products. Simultaneously, livestock production is associated with regular and ongoing supply of organic fertilizers, either as manure from the housing or as deposits on pastures. Up to 90% of ingested N is recycled via dung and urinary excretion of grazing animals (Haynes and Williams, 1993). Therefore a close relationship between organic fertilizers and grassland production is found frequently as close nutrient cycle. However, there is a gap between available nutrients and the recycling in plant biomass.

Generally, to meet crop requirements, several nutrients are applied continuously of which **nitrogen** (**N**) is the most prominent (chapter 4.2). In total 110 Mio. tonnes of mineral **N** fertilizer are spread world-wide annually on agricultural land, followed by **potassium** and **phosphate** (Faostat, 2016). Excess **N** applied to agricultural systems may discharge. Initiated by (de)nitrification, emissions of nitrous oxide (N_2O) and nitrogen monoxide (**N**O) induce climate change and ozone depletion, while volatilization of ammonia (NH_4/NH_3) causes harmful air quality damage, eutrophication or indirectly climate change. During the last 50 years, agricultural greenhouse gas (GHG) emissions increased significantly by 96%, which are linearly related to the **N** intensity of production. Leaching of nitrate (NO_3) from the root zone and runoff **N**H_4 contaminate groundwater, rivers, lakes and marine ecosystems, causing harmful externalities for biodiversity and drinking water (Good and Beatty, 2011; Wba, 2016). Derived from national **N** balances for the EU-27 states, Van Grinsven *et al*. (2014) calculated an average **N** use efficiency of only 30% for the agricultural sector. **Nitrogen** loss abatement by improved plant **N** uptake and increased **N** retention is therefore highly required. To reduce and prevent **nitrate** discharge, the EU nitrates directive (ND, 91/676/EWG) was initiated, prescribing a maximum area based application rate of 170 kg **N** ha^{-1} $year^{-1}$ from organic fertilizers or lower. Additionally, **phosphorus (P)** has become an important negative externality for surrounding ecosystems due to detrimental effects for water (Wageningen UR, 2014). In future the **P** management will be restricted widely if the accurate utilization on farms will not be adapted soon. A good planning of the fertilization consequently is paramount for high nutrient efficiency (i.e. low losses and high yields).

<u>Organic fertilizers reduce fertilizer bills</u>

In view of the environmental issues, there is a need to utilize organic fertilizers very efficiently. This is in particular important for grassland as high shares of nutrients digested in livestock are related directly to the feeding of grass products. High uptake efficiency additionally reduces costs for mineral fertilizers. A high **N** uptake is reached by adapted fertilizer type, amount, timing, application technique and placement (Dinnes *et al*., 2002; Quakernack *et al*., 2012). Adequate fertilization timing emphasizes the spring and harvests. Fertilization after the last cut (i.e. in September or October) contrarily increases losses to up to 25% of applied N (Smith *et al*., 2002).

North-Western Europe is favorable for dairy production. Except for Ireland, the proportion of cut grassland dominates the feed rations for intensive dairy cow production with up to 6 cuts per year. The fertilizer demand is derived from the respective forage yield, as plants accumulate nutrients as function of their biomass dry-matter (DM) production. Overfertilization increases the losses to the environment and therefore costs. Moreover, it results in a deterioration of the botanical composition with an increase of nitrophilous weeds. Consequently, good knowledge of the yield level is of paramount importance to achieve appropriate fertilization and to save money. For very good managed grassland plots in experiments, gross yields of up to 16 t DM/ha/year were reported (Nevens and Reheul, 2003; Trott *et al*., 2004). In the agricultural practice, however, yields frequently range between 8 and 10 t DM/ha/year (Van den Pol-van Dasselaar *et al*., 2015). Grassland soils with good contents of nutrients should be supplied with the amounts exported. To supply the sward with nutrients, knowledge on the distribution of the grass yield is important. Table 4.3 gives an overview for several scenarios of management intensity.

Table 4.3. Distribution of the DM yield (%-yield share of the 1th – 6th cut) as function of the cutting frequency. (www.gruenland-online.de, unpubl. data of Laimburg Research Centre, adapted).

Cut frequency (cuts year^{-1})	contribution of each cut to the annual forage yield (%)					
	1st cut	2nd cut	3rd cut	4th cut	5th cut	6th cut
2	62	38				
3	47	28	26			
4	40	25	20	15		
5	30	20	20	17	13	
6	30	25	15	15	10	5

According to Table 3, the first two cuts deliver between 55 to 75% of the total annual yield. Appropriate fertilization practice harmonizes crop demands and nutrient delivery for each harvest.

Planning of organic fertilization

The primary nutrients delivered in organic fertilizers are **N**, **phosphorus** (**P_2O_5** or **P**), **potassium** (**K_2O** or **K**) and **magnesium** (**MgO**), while also **CaO, sulphur, copper, manganese, zinc, boron** and **molybdenum** may be available. Long-term dose-response trials derived reliable relationships between the yield and the nutrient demand. Approximately, the demand for intensively managed grassland is approximately **2.5 kg N, 0.8 kg P_2O_5, 3.1 kg K_2O and 0.45 kg MgO per 100 kg DM yield** in a 4-cut system. Consequently the area-based nutrient demand increases with the yield level as shown in Table 4.4. The presented nutrient demand only applies to intensive production. The fertilization of intensive grassland aims to meet the demand to assure for high yields and quality. It should not be used to compute the demand of species-rich grasslands which do not need any external nutrient inputs. If nature conservation, i.e. high biodiversity is focused on grasslands, the nutrient input via fertilizer should thus be avoided. Otherwise species disappear out of the swards.

Table 4.4. Example of nutrient demand of grassland of varying yield levels. The mineralization is taken into account.

yield level [t DM/ha]	N [kg/ha]	P_2O_5 [kg/ha]	K_2O [kg/ha]	MgO [kg/ha]
6	150	48	186	27
7	175	56	217	31
8	200	64	248	36
9	225	72	279	41
10	250	80	310	45

Fertilization strategy

According to the Nitrates Directive (1991), a maximum supply of 170 kg **N/**ha/yea derived via organic fertilizers may be applied on farms. In groundwater sensitive regions, i.e. nitrate vulnerable zones (i.e. DEFRA, 2018) this value may range lower. Ask your advisor for this. The nutrient contents of organic fertilizers are highly variable in relation to the management, feeding, year and time of the year. An important prerequisite for accurate organic fertilization is the chemical analysis of the available fertilizers on the farm. To give rough estimates, table 4.5 shows some average values for specific organic fertilizers. These values, however, do not apply for specific farming situations.

Table 4.5. Nutrient contents of some organic fertilizers (derived from: Baumgartner *et al*., 2006; Elsäßer, 2009; Klocker *et al*., 2017; Agricultural chamber of North Rhine-Westphalia, 2018).These values give only rough estimates. The actual contents of organic fertilizers on each farm may vary strongly in relation to the management, feeding, year and time of the year. Therefore annual analyses of fertilizer samples are required for optimal fertilization.

organic fertilizer	total N	NH4-N	P2O5	K2O	MgO
	kg/m³ or kg/t	**kg/m³ or kg/t**	**kg/m³ or kg/t**	**kg/m³ or kg/t**	**kg/m³ or kg/t**
general fertilizer					
liquid manure	3.5	1	1.9	5.8	1.1
solid manure	4.2	0.3	3.5	6.1	2.2
Slurry	2.7	1.7	0.1	9	0.4
biogas residue	3.2	1.5	1.8	5.8	1
liquid manure					
Cattle					
young stock grass-based	3	-	1.2	4.7	-
young stock arable-based	2.4	-	1	4	-
dairy cows grass-based	3.7	-	1.4	5.3	-
dairy cows arable-based	3	-	1.3	4.3	-
beef cattle	3.6	-	1.5	3.7	-
solid manure					
Cattle	3.2	-	2.9	5.9	-
Horse	2.3	-	1.5	3	-
Sheep	4.3	-	2.1	4.9	-
Pigs	5.8	-	5.1	5.5	-

Generally, the fertilization level follows the actual demand, i.e. the yield. For some nutrients, however, partly excess fertilization during one year to increase the soil storage may be valuable (i.e. lime). The nutrient requirements are determined by the yield and the yield level should be known for each site and harvest. Additionally, it is important to understand that only parts of the nutrients in organic fertilizers will become available for plants during the year of application. For liquid organic dairy manure, for instance, approximately 50% of the total **N** content or at least the **NH_4-N** share will become available in the year of application. Approximately 10% of the total slurry-**N** may become available during the subsequent year. One example of a grassland **N**-fertilization strategy is given in the following **example 1**:

N fertilization (kg N/ha) = N demand (kg/ha) – soil N (kg/ha) – N from legumes (kg/ha) – N from organic fertilizer N preceding year (e.g. 10 % of organic fertilizer N of the preceding year)

that means according to Table 4.4 and a yield level of 10 t DM/ha:

N fertilization = 250 - 10 - 15 - 17 = 208 kg N/ha

A value of 17 kg N/ha from organic fertilizer of the preceding year means that 170 kg N/ha were applied in that year (i.e. 10% of preceding total organic N fertilization).

Here the **soil N** refers to the expected mineralization during the growing season which considers the soil humus content in the system in Germany. The proportion of legume-**N** is higher under less intensive management and in regrowths after the first harvest. In relation to the time of the growing season, the climatic and soil conditions and the leguminous species, between 3 to 6 kg of N are supplied per %-share to the yield. The **N** fertilization scheme varies in relation to country-specific regulations. The example refers to regulations formulated in Germany. For grazing systems in Ireland the additional **N** input is based on the stocking rate in relation to the timepoint of the growing season (TEAGASC, 2018). In Sweden the Advisory Board for Agriculture is responsible. Ignoring the good fertilization practice guidance may be charged by local governance. Therefore adapted consideration of regulations regarding the fertilization practice, are necessary. Advisors can help to fulfill the regulations.

Table 4.6 gives an example for the application of fertilizers to grassland with a yield level of 10 t DM/ha. In this example a liquid dairy manure with the listed contents of nutrients is applied. The plant demand refers to a 4-cut grassland for conditions in Germany. Again, in other countries the specific crop requirement may range lower or higher. According to Table 4.6, in total **50 m^3/ha/year** of slurry are applied due to the demand of MgO which is met with this amount. If the total grass demand exceeds the amounts of nutrients supplied with organic fertilizers, additional mineral fertilizers may be used for the respective cuts. For the share of each cut to the total annual yield, consider Table 4.3.

Table 4.6. Fertilization grassland at a yield level of 10 t DM/ha with liquid dairy manure and resulting mineral external fertilizers. Example 1 refers to above mentioned calculation of N demand.

example of nutrient content of liquid dairy manure		specific nutrient demand	nutrient demand	N demand **expl. 1**	possible manure rate	nutrients applied with **50 m³/ha** manure	mineral fertilizer
nutrient	kg/m³	kg/100 kg	kg/ha	kg/ha	m³/ha	**kg/ha**	kg/ha
total-N	4	2.5	250	208			
NH_4-N	2.3				90	115	93
P_2O_5	1.5	0.8	80	80	53	75	5
K_2O	4.5	3.1	310	310	69	225	85
MgO	1	0.5	50	**50**	**50**	50	0

Potassium fertilization in excess may cause detrimental effects for the livestock. A threshold for maximum fertilization is 100 - 120 kg **N** ha^{-1} and 150 kg **K_2O** ha^{-1}. The recovery of **N** further depends on the application technique with shallow injection or acidification increasing the **N** contribution by up to 20% in comparison to broad-cast application. For further information about the adequate handling of fertilizers consider advisory tables, booklets, statements and recommendations (e.g. agricultural chambers, DEFRA, TEAGASC, Jordbruksverket, Ministries etc.).

4.6 Other macro- and micronutrients

Martin Komainda (University of Göttingen), Giovanni Peratoner (Laimburg Research Centre), Nora Schiebenhöfer, Johannes Isselstein (University of Göttingen)

On grazed grasslands the nutrient supply via grazing animals should be taken into consideration when planning the fertilization. On grazed land the demand of **P, K, Mg** and **sulphur S** is usually much lower than on cut grassland.

Sulphur (**S**) represents an important nutrient for grasslands. Mostly **S** depletion occurs if above-average precipitation during winter induced **S** leaching. In spring the analysis of soil samples for the content of mineralized **S** (**S_{min}**) represents a good indicator for the fertilization requirement. For an efficient fertilization of **S**, however, an adequate and representative forage sample should be analyzed. Inadequate **S** supply is indicated by a nitrogen-to-sulphur (**N:S**)-ratio of ≥ **15:1**. According to this, **S** fertilization may be required. **Sulphur** deficiencies can be expected at high supply levels of mineral **N**, whilst they are less likely if organic fertilizers are used. **Potassium, magnesium** and **natrium** affect each other in the plant uptake and the digestion of the animal. Generally, 1% **potassium** of the DM is sufficient to meet the livestock requirement. Most soils, however, are low in **potassium** contents due to leaching. Therefore fertilization is required in managed grasslands. However, if **potassium** is accumulated in plants in excess, it may induce metabolic disorder in animals due to antagonism with **magnesium** and consequently induce grass tetany. The incidence of grass tetany increases with **magnesium** contents < 0.2% in the DM and at > 3% **potassium** and >20% crude protein in the DM. This can occur in very young plant material early in the year. Clay soils are usually rich in **potassium** and do not require any external input. Acidic and light-sandy soils are usually low in contents of **magnesium**, whereas volcanic and clay soils have higher contents. Soils rich in **natrium** are found in the heavy marsh lands located near the coastal line and also soils of aridic zones. **Potassium** and **natrium** may be antagonistic. **Natrium** is important for the animal and should therefore be supplied separately because it may block physiologic processes in plants, which are induced by **potassium**. **Selenium** is important for the livestock animal. For lactating dairy cows, the concentrate usually contains **selenium**. **Selenium** contents in the plants mainly depend on the **selenium** content of the soil. In areas with low **selenium** soil contents, the supply of the animals cannot be ensured via grass biomass without external supply. For extensively reared beef cattle or horses, **selenium** deficiency is therefore found frequently. Animals require between 0.1 and 0.3 mg **selenium** kg/DM. Due to toxic effects, the maximum **selenium** fertilization is limited to 8 g/ha. For instance, Klotz *et al*. (2012) showed a way to fertilize **selenium** by mixing with liquid manure which reduces application costs. Fertilization of **selenium** is difficult on soils with low pH. Consequently adequate liming is important. **Micronutrients** should be applied if a deficiency is recognized after plant or soil analysis. Predominantly forage plants grown on arable land, likely alfalfa, may have demand for specific micronutrients, e.g. molybdenum. Advisors can help to choose appropriate fertilizer products. Figure 4.3 gives an overview of the relationship between plant availability and micronutrients. Table 4.7 gives an overview for authorities for fertilization law in some EU-States.

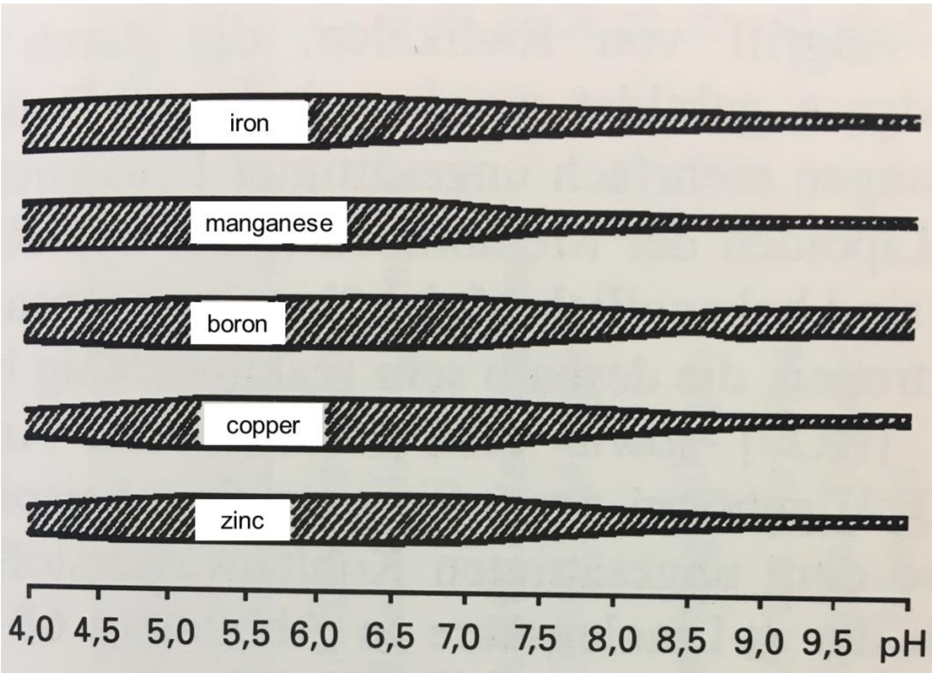


Figure 4.3. Plant availability of micro nutrients in relation to the pH of the soil. The width of each strip represents the solubility (adapted from Schilling, 2000).

Table 4.7. Overview of responsible authorities with respect to Agriculture in each country of the partners in Inno4Grass (date: 19.12.2018).

Country	Responsible for questions of Agriculture	webpage
Belgium	Foreign Affairs, Foreign Trade and Development Cooperation	https://diplomatie.belgium.be/en/policy/coordination_european_affairs/policy/agriculture_and_fisheries
France	Ministry of Agriculture	http://agriculture.gouv.fr/english-contents
Germany	Landwirtschaftskammer, Landesamt für Landwirtschaft, Ministry of Agriculture	https://www.lwk-niedersachsen.de/ , https://www.bmel.de/EN/Homepage/homepage_node.html
Ireland	TEAGASC	https://www.teagasc.ie/contact/
Italy	Ministry of Agriculture	https://www.politicheagricole.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/202
Poland	Ministry of Agriculture	https://www.gov.pl/web/rolnictwo/
Sweden	Swedish board of Agriculture	https://www.jordbruksverket.se/swedishboardofagriculture/engelskasidor/crops/plantnutrients.4.6621c2fb1231eb917e680003205.html
the Netherlands	Ministry of Agriculture, Nature and Food Quality	https://www.government.nl/ministries/ministry-of-agriculture-nature-and-food-quality
List for responsible authorities in EU-member states		https://ec.europa.eu/agriculture/links-to-ministries_en

5. Environment and biodiversity

5.1 Carbon sequestration

Agnes van den Pol-van Dasselaar (Wageningen University / Aeres) and Felicitas Kaemena (LWK)

<u>*Carbon sequestration as an ecosystem service*</u>

Grasslands are well-known for their contribution to food production (milk, meat). Food production is an important service that grasslands deliver. Grasslands do deliver many other services and goods as well, the so-called ecosystem services. Ecosystem services are the benefits that humankind gains from its interaction with natural resources, in this case with grasslands.

They can be divided in four groups (MEA, 2005):

- Provisioning services: products obtained from ecosystems, e.g. production of food, water
- Regulating services: benefits obtained from the regulation of ecosystem processes, e.g. control of climate and disease
- Cultural services: non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, e.g. recreation and beauty of the landscape
- Supporting services: ecosystem services that are necessary for the production of all other ecosystem services, e.g. nutrient cycles, crop pollination.

Ecosystem services are important for the farmer and for the broader society. Some examples of ecosystem services that grassland deliver are shown in Figure 5.1. Carbon sequestration is one of them.

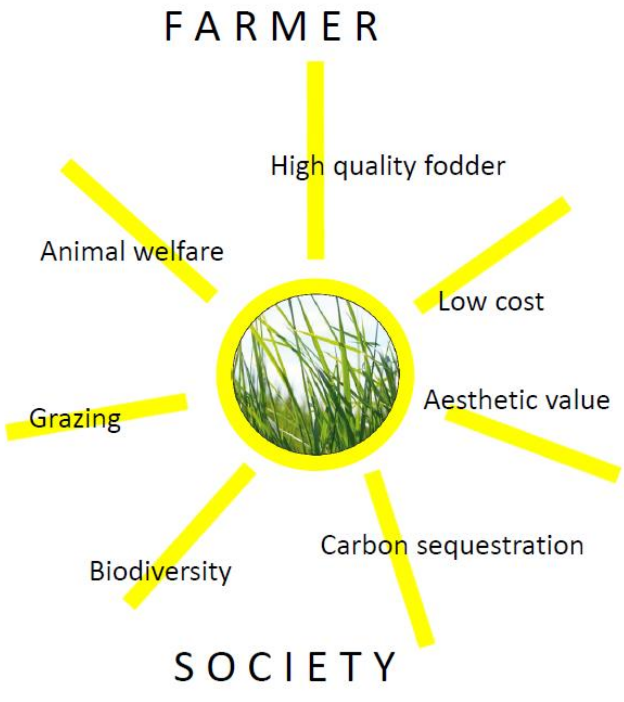


Figure 5.1. Selection of ecosystem services that grasslands provide to farmer and society (Van den Pol-van Dasselaar *et al.*, 2018a).

Carbon storage

Soils are important to combat climate change since they are capable to store enormous amounts of carbon (C). They act as a huge C reservoir. Figure 5.2 (based on modelling) shows the differences in soil organic C content between the North and South of Europe. The organic C content of soils is higher in the North than in the South of Europe. This is mainly due to abiotic factors (climate, etc.).

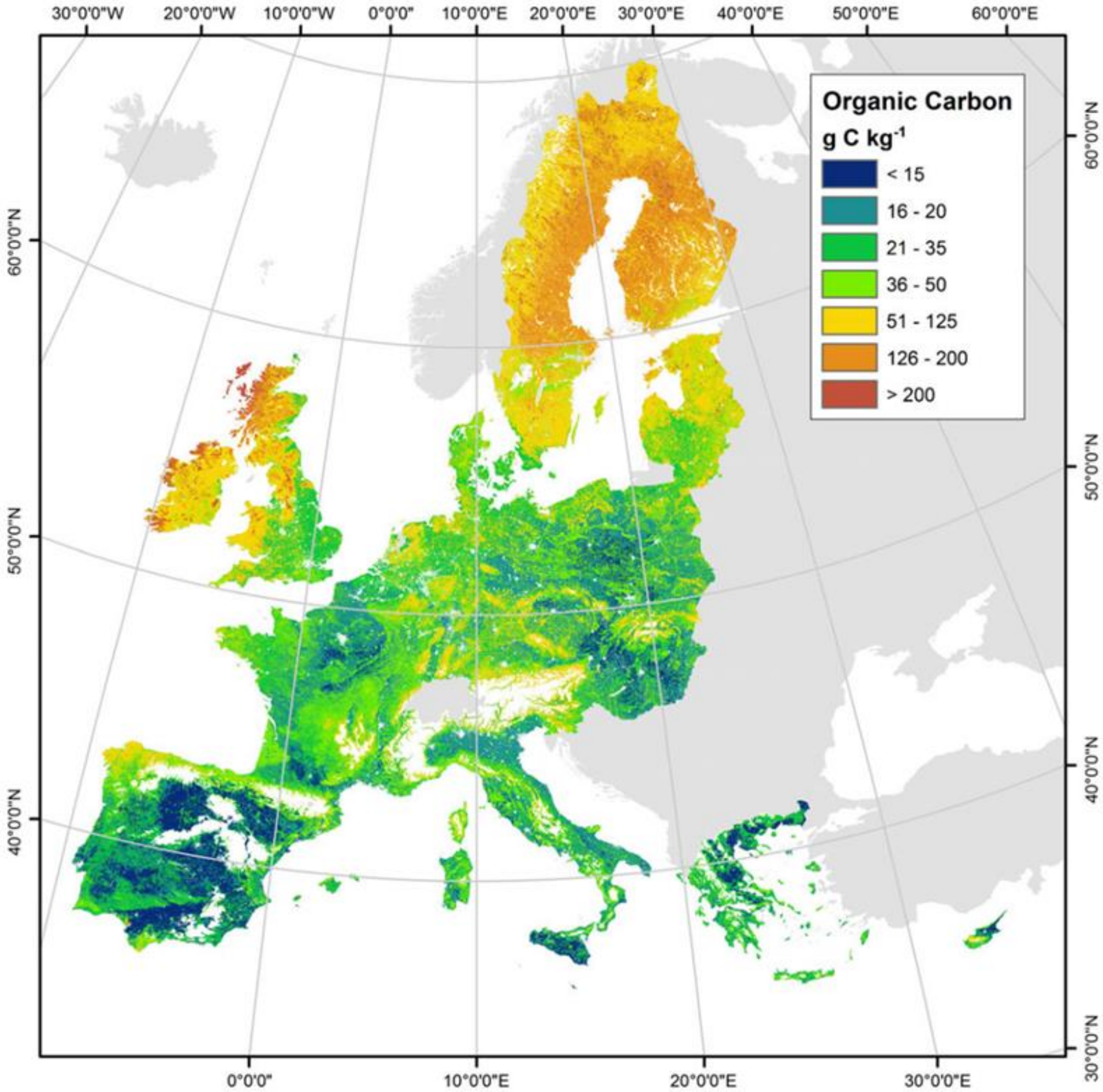


Figure 5.2. Map of predicted topsoil organic carbon (C) content (g C kg^{-1}) (De Brogniez *et al.*, 2015)

Next to abiotic factors, management factors also play a role in C storage and C sequestration. The C storage capacity of grasslands is much higher than of arable lands. If grasslands are ploughed, considerable amounts of C are lost. To combat climate change, it is therefore important to maintain the current C stocks and prevent ploughing of grasslands as much as possible.

Effect of grassland management on carbon sequestration

Many types of grassland have not yet reached their maximum storage capacity and are able to store additional C. This additional C storage is called C sequestration. Carbon sequestration is important to combat climate change. But, as said previously, even when no additional C is sequestered, grasslands are very important in relation to climate change, since they store enormous amounts of C. The extent to which additional C can be taken out of the atmosphere by grasslands and stored in the soil will determine the overall role of grasslands in mitigating the impact of increased emissions.

A literature review of the EIP-AGRI Focus Group ‘Grazing for carbon’ (Van den Pol-van Dasselaar *et al*., 2018b) showed that there is net C sequestration within grassland systems in general, but in a mixed grazing and cutting system there is less C sequestration than under a pure grazing system (Figure 5.3).

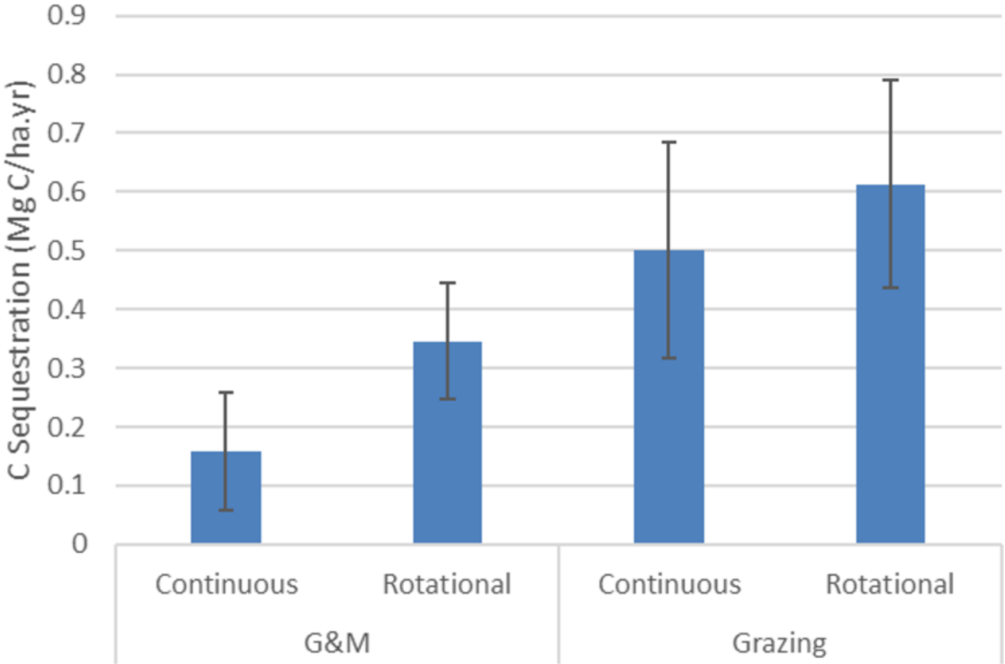


Figure 5.3. Mean carbon (C) sequestration rate (Mg C ha^{-1} yr^{-1}) for mixed grazing and cutting systems (G&M) or grazing only systems (Grazing) (results of literature review Klumpp *et al*. in Van den Pol-van Dasselaar *et al.*, 2018b).

Soil management and abiotic factors both affect C equilibrium and C stock. The key challenge for sustainable grazing livestock systems is to find the optimal type of management to combine animal production with the delivery of other ecosystem services like C sequestration.

The effect of grazing on C sequestration is rather complex and is affected by the grazing intensity (Figure 5.4). Many processes play a role, and these are each individually affected by abiotic factors and management factors. Effects of grazing are driven by plant tissue removal (defoliation), excretion (urine and dung deposits) and trampling, which exerts mechanical pressure and causes physical damage to the vegetation where animals pass repeatedly. In the short term, grazing results in a reduction in aboveground standing biomass, as well as changes in plant nutrient status. If there is much dead plant material in the sward that is shading the live leaves, grazing can allow light to penetrate into the plant canopy and encourage new tiller formation, enhancing primary productivity. Conversely, if grazing is too intense or the period between successive grazing events is too short, the amount of live leaf can be so reduced that light interception falls, growth/carbon capture is reduced and litter production is low (i.e. reduction in C inputs to soil). Between these two extremes, there is relatively little change in growth with changes in grazing pressure. However, the quality of the herbage and the production of litter still respond to changes in grazing pressure within this range. Higher grazing pressure increases pasture regeneration and herbage quality (as long as there is sufficient N available), but reduces litter production, and vice versa. There is a trade-off between quality (promoting animal production) and litter production (promoting C sequestration). What constitutes low/medium/high grazing pressure varies between locations and over time; the lower the pasture growth, the lower the grazing pressure or the longer the period between grazing events, and vice versa. The key aim for sustainable grazing livestock systems is to find the optimum stocking rate where the optimum grass intake coincides with a certain amount of C sequestration in the soil.

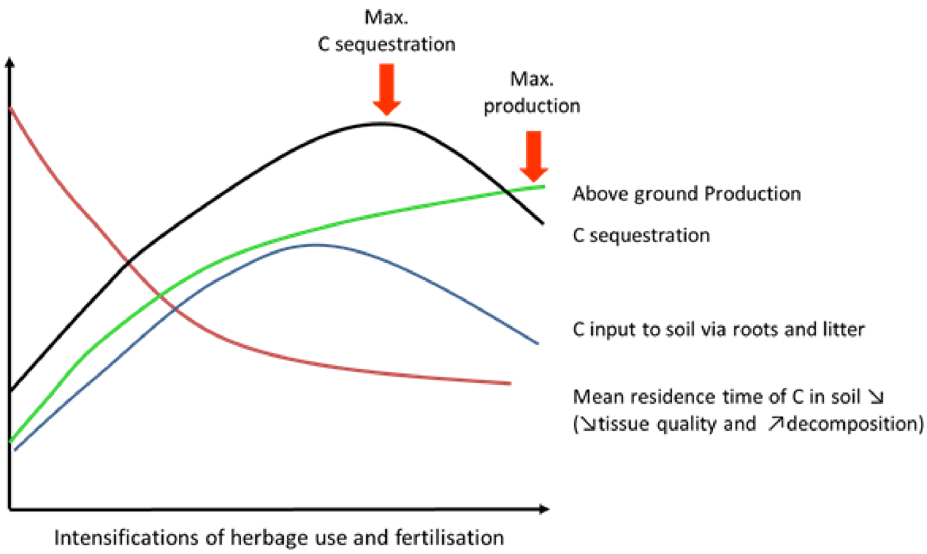


Figure 5.4. Effects of grassland intensification by grazing, cutting and fertilisation on C inputs, mean residence time of soil organic C and C sequestration (adapted from Soussana & Lemaire, 2014).

5.2 Greenhouse gas emissions

Agnes van den Pol-van Dasselaar (Wageningen University / Aeres) and Felicitas Kaemena (LWK)

Climate change

During the last decades the effects of climate change have received a lot of attention. Moderate warming and more carbon dioxide in the atmosphere may help some plants to grow faster. However, more severe warming, floods, and drought may reduce yields. Livestock may be at risk, both directly from heat stress and indirectly from reduced quality of their food supply.
To deal with climate change in agriculture, two pathways are possible:

- Mitigation
- Adaptation

Mitigation options in agriculture are options which reduce the emissions of greenhouse gases (CO_2, N_2O and CH_4) from agricultural production systems.
Adaptation options describe ways for agricultural production systems to adapt to future climatic conditions (like global warming, larger climatic variability and increased frequency and severity of droughts and floods). Often mitigation options and adaptation options interact.

Options to mitigate greenhouse gas (GHG) emissions from animal production systems are strongly linked to the N and C cycles in those systems. The four key components with their respective main GHG are:

- Manure/fertiliser: mainly N_2O and CH_4 emissions
- Soil: mainly CO_2 and N_2O emissions
- Crop/feed: mainly N_2O emissions
- Animal: mainly CH_4 emissions (as a result of enteric fermentation)

The sources and sinks of the various greenhouse gas emissions from animal production systems have been identified and the variation in their size has been evaluated. Many mitigation options have been tested experimentally and the results have been documented in several reviews (e.g. Vergé *et al*., 2007). Models have been developed to predict GHG emissions and to evaluate mitigation strategies. In a similar manner adaptation options have been studied (e.g. Olesen *et al*., 2011), which is particularly important for areas which are most vulnerable to climate change. Research results show numerous interactions between mitigation and adaptation in the context of different environmental and socio-economic conditions. Generally, limited information is available on the quantification and comparison of synergies and trade-offs, and few papers report on this (e.g. Smith and Olesen, 2010).

Mitigation and adaptation options

Van den Pol-van Dasselaar and Bannink (2014) provided a qualitative overview of mitigation and adaptation options in livestock production systems, and of their synergies and the trade-offs between individual GHG (Table 5.1). It is based on a review of available literature and expert judgement. The options are strongly linked to changes in the N and C cycles of the farming system. Four categories of options are distinguished in Table 5.1, at the level of:

- manure/fertiliser
- soil
- crop/feed
- animal.

Many adaptation and mitigation options in Table 5.1 are linked to grasslands. Since synergies and trade-offs between GHG exist for adaptation and mitigation options, accurate predictions of the effects of these options are needed to tailor them in the context of specific farming conditions. The effects of climate change may cause a reduced efficacy or applicability of mitigation strategies. It may lead to lower yields due to elevated temperatures and fluctuations in water availability. Furthermore, in many countries, the impact of agriculture on climate is a less important issue, because of socio-economic reasons such as for example addressing famine (Vergé *et al*., 2007).

Table 5.1 focuses on options at the field and the animal scale. It is important to have a clear understanding of the possible options at that scale, since it is the scale where farmers make their day-to-day decisions. However, it is also important not to forget the regional and global effects, since decisions at the scale of field and animal will affect the global scale as well. For example, the impact of rising food demands means, other things being equal, that a reduction in food production in a certain region would result in increased food production elsewhere. This can result in net increase in global GHG emissions, if the countries expanding food production were unable to produce food with low emissions intensity (Schulte *et al.*, 2011).

Table 5.1. Qualitative overview of mitigation and adaption options in livestock systems at the level of manure/fertiliser, soil, feed/crop and animal, and their synergies and trade-offs (Van den Pol-van Dasselaar and Bannink, 2014).

Option	Effects on mitigation (+)	Effects on adaptation (+)	Mit.pot. CH4 (-/+/++)	Mit.pot. N2O (-/+/++)	Mit.pot. CO2 (-/+/++)	Mitigation variability (variable/robust)	Importance in mitigation (low/high)	Adaptation variability (variable/robust)	Importance in adaptation (low/high)	Productivity impacts (-/+)	Costs (high/low/?/benefit).	Future measure / ready to use	Applicability by farmers (easy/difficult)	Acceptability for farmers (poor/good)
MANURE / FERTILISER														
Fertilisation rate	+	+	-	++		rob	high	rob	low	+	ben	ready	dif	good
Fertiliser type	+			+		var	high			+	ben	ready	dif	good
Fertiliser application	+			+		rob	high			+	ben	ready	dif	good
Cover slurry stores/manure heaps	+		++	-	+	rob	low				low	ready	easy	good
Manure cooling	+		+			rob	low				high	future	dif	poor
Manure treatment	+		++	-	+	rob	high				?	ready	dif	good
Filtering CH4 from barns	+		+	+		var	low				high	future	dif	poor
SOIL														
Reduced/zero-tillage	+	+		-	++	rob	high	rob	high		low	ready	dif	poor
Prevent soil compaction	+			+	+	var	low			+	low	ready	dif	good
Water management	+	+		+	+	var	low	var	low	+	low	ready	dif	good
Irrigation		+		+		var	low	var	low	+	low	ready	dif	good
Restoring degraded lands	+	+		+	++	rob	high	rob	high	+	high	ready	dif	poor
Pasture reclaiming/recovery	+				++	rob	high				low	ready	easy	good
Incorporation crop residues		+		-	+	rob	low	rob	low	+	?	ready	easy	poor
CROP / FEED														
Crop rotation	+	+	+	+	++	rob	low	var	low		low	ready	easy	good
Perennial crops	+			+	+	rob	low				low	ready	easy	good
Legumes and mixtures	+		-	++	+	rob	low			+	ben	ready	easy	good
New pasture species	+		+			var	low			+	low	future	dif	good
Improved crop varieties	+		+	+		var	low			+	low	future	dif	good
Novel crops	+	+	+			var	low	var	low		low	future	dif	poor
Cover crops	+	+		+	++	rob	low	rob	low	+	low	ready	easy	poor
Conversion to grass	+				++	rob	low				low	ready	easy	good
Reforestation	+				+	var	low			-	high	ready	dif	poor
Optimal forage management	+		+		+	var	low			+	ben	ready	easy	good
Biodiversity		+						var	high	+	low	ready	easy	poor
Plant breeding		+						rob	high	+	high	future	easy	good
Use climate forecasting		+						var	high	+	ben	ready	easy	good
Different planting dates		+						var	low	+	low	ready	easy	good
Conservation as a buffer		+						rob	low		low	ready	easy	good
Mixed versus single species grass		+						var	low	+	low	ready	easy	good
Agroforestry		+			++	rob	high	rob	low		high	ready	dif	poor
Optimal grazing	+	+			+	var	low	var	high	+	ben	ready	dif	good
Increased feed digestibility	+		++			rob	high			+	high	ready	dif	good
Feed analysis	+		+	+		rob	low				high	ready	easy	good
Improving roughage quality	+		+			rob	high			+	low	ready	dif	good
More concentrates	+		+	+	-	rob	high			+	high	ready	easy	good
Improving grass quality	+		+			rob	high			+	low	ready	dif	good
Use of silage maize	+		++		-	rob	low				low	ready	easy	good
Additives in general	+					var	low				high	future	easy	poor
Additive nitrate	+		++			rob	low				high	ready	easy	poor
Matching supply and demand	+		+	+		rob	high			+	ben	ready	dif	good
Supplemental feeding		+	+			var	low	rob	high	+	high	ready	easy	good
ANIMAL														
Rumen control via breeding	+		+			var	low				high	future	dif	poor
Immunological control	+		+			var	low				high	future	dif	poor
Less consumption animal products	+		++	+		rob	low					ready	easy	poor
Increased production in general	+		++	+		rob	high			+	ben	future	dif	good
Incr prod extensive systems	+		++	-		rob	high			+	ben	ready	easy	good
Incr prod intensive systems	+		+			rob	high			+	ben	future	dif	good
Animal breeding	+	+	+	+		var	low	var	high		high	future	dif	good
Animal management	+		+			var	low				ben	ready	dif	good
Animal manipulation	+		+	+		var	low				high	ready	easy	poor
Replacement rate cattle	+		++	+		rob	high			+	ben	future	dif	good
Cooling of animals		+						rob	high		high	ready	easy	good
Livestock mobility		+						var	high		low	ready	dif	good
Animal health		+						var	low	+	low	future	dif	good

<u>Effect of grazing versus no grazing on GHG emissions</u>

Looking at the potential effect of grazing versus no grazing in relation to climate change, the most important difference between grazing and keeping cows indoors all year is the place where the dung and urine land: some in the pasture, or all in the cowshed. When dung and urine are deposited in the field, a large amount is deposited on a small area where the minerals cannot be used – at least, not in the short term – and thus losses are more likely. Dung and urine collected from the cowshed can be used as fertilizer. This improves the nutrient use efficiency and reduces the need to buy fertilizer, while yields remain the same. Keeping cows indoors all year can reduce a farm's imports of nitrogen by about 50 kg ha^{-1} yr^{-1} compared to grazing. In addition, grazing affects the type of nitrogen loss. During grazing, relatively large amounts of nitrate may be leached and there may be considerable denitrification. Furthermore, there may be relatively large emissions of nitrous oxide (N_2O). By contrast, collecting dung and urine from the stable and spreading it on the land, as is the case when keeping cows indoors all year, results in more ammonia volatilization. This ammonia volatilization may be partly reduced by adapting the feed strategy (less protein in the ration). When keeping cows indoors all year, the energy use and hence the CO_2 emissions may also be larger because there is much more use of machinery. The grazing system does not affect methane emissions from grasslands themselves. The larger amount of manure in the slurry pits when keeping cows indoors all year, however, may lead to more methane emissions. The overall effect of grazing is illustrated in Figure 5.5 that shows the greenhouse gas emissions of 46 farms with different grazing intensities (full day grazing, half day grazing and access to pasture) (Lasar, 2017). The consideration of the groups and the different greenhouse gas sources provide a good insight into the relationship between milk production and CO_2 emissions. It becomes clear which areas are particularly sensitive and show a risk of high emissions. Differences between grazing systems are summarised in Table 5.2.

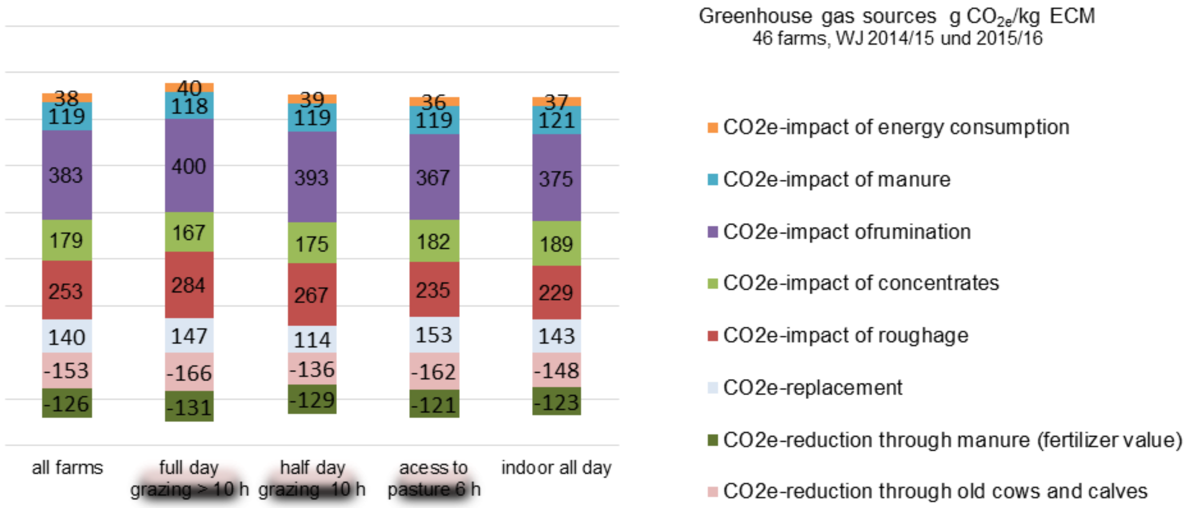


Figure 5.5. Greenhouse gas sources (g CO_2e/kg ECM: CO_2-equivalent is a unit of measurement to compare the effect of different greenhouse gases on warming with that of CO_2) of 46 farms with different grazing intensities: full day grazing (> 10 hours/day); half day grazing (> 6 hours/day); access to pasture (< 6 hours/day) and indoor all year.

Table 5.2. The effect of grazing on various environmental aspects. The score ranges from - - to ++, with ++ signifying that the system concerned scores negative for the point in question, e.g. high leaching, high losses (Van den Pol-van Dasselaar *et al.*, 2008).

Viewpoint	Unrestricted grazing	Restricted grazing	No grazing
Nitrate leaching, N_2O emission, N losses	+	-	- -
P losses	+	+/-	-
Ammonia volatilization	- -	-	+/-
Energy use, CH_4 emission	-	+	++

5.3 Water quality

Felicitas Kaemena (LWK) and Leanne Aantjes (Aeres)

Water law requirements - legal background

The Water Framework Directive (WFD) forms the regulatory framework for the protection of water bodies in the European Union. One of its aims is to maintain or gradually improve the material and quantitative status of surface waters and groundwater across the board. Special regulations are laid down in the Groundwater Directive as a daughter directive to the EC Water Framework Directive. According to this directive, the following quality standards apply throughout Europe for the assessment of good chemical status: 0.1 g/l for active ingredients in pesticides for individual substances and 0.5 g/l as the sum value of all proven pesticides and their degradation products.

Furthermore, the guideline for nitrates specifies a quality standard of 50 mg NO_3/l. If the nitrate limit value of 50 mg NO_3/l is exceeded or 75% of the limit value is reached, measures to reverse the trend are necessary. The limit value of 50 mg NO_3/l groundwater is also laid down in the Nitrates Directive.

According to the Water Resources Act, harmful or detrimental changes to water bodies are to be avoided.

Permanent grassland - groundwater protection

As a rule, grassland use is carried out on the less efficient soils and is characterised by reliably low N min values when using cuttings. As a measure to preserve grassland, the energetic use of the vegetation to ensure low N output and avoid upheavals is desirable.

Permanent grassland is primarily used to provide fodder for dairy cattle. It is also of great importance as a landscape-determining element and for the protection of resources. Further use may consist in the provision of biomass for fermentation, especially in regions where other forms of use no longer exist. In general, the use of grassland for energy purposes is positive if it ensures the maintenance of grassland.

The composition of the population varies from grassland to grassland and depends on cultivation (use, fertilisation, maintenance) and location factors (climate, soil, terrain). Experience from water protection consulting shows that N surpluses decrease with increasing cutting use. Maintenance measures should ensure the long-term maintenance of a dense grassland sward so that nutrient yields remain low and a change to grassland renewal can be avoided in the long term. Reseeding serves to eliminate stand gaps and to maintain or establish the desired composition of the grassland sward. It is carried out in March / early April or towards the end of August. The late summer date benefits from the lower growth rate of the old sward, but requires sufficient soil moisture. If a renewal of the sward is unavoidable, an uninterrupted procedure with herbicide application and subsequent sowing using the through-seeding technique is recommended. This can largely prevent nitrate leaching as a result of the otherwise unavoidable humus mineralisation and a disturbance of the soil structure. Particular importance must be attached to the care of the grassland.

Low autumn N min values of ~30 kg N/ha and N concentrations in leachate tending towards zero can be measured under grassland. The autumn N min values can be reduced compared to grazing by cutting. From a water protection point of view, grassland conservation is particularly important on sites with high mineralisation.

<u>Conversion of arable land into grassland and extensive grassland management</u>

From the point of view of groundwater protection, permanent grassland offers several advantages over arable land use:

- Year-round greening with high N uptake
- No tillage, i.e. low rates of mineralisation (exception: reseeding)
- Less use of crop protection agents

Added to this is the very low susceptibility of grassland to erosion. The nitrate emissions under grassland are therefore usually significantly lower than with arable land use. Exceptions are grazing livestock with high stocking densities and grassland upheaval for grassland renewal or transfer to arable land use. In water catchment areas, in addition to the conversion of arable land into grassland, the conservation and extensive management of grassland is also promoted.

<u>Example of Lower Saxony: use of nature conservation, compensation and replacement measures and networking with drinking water protection measures</u>

The success of groundwater protection measures under the Lower Saxony cooperation model must be measured against a large number of target criteria, the most important of which are listed below in key points:

- Maintaining good groundwater quality or, where necessary, improving or rehabilitating groundwater quality by reversing the trend in quality development;

- Achieving good acceptance among the main target groups of land users and the authorities and institutions involved;
- Compliance with the financial framework set by the revenue from the water abstraction fee;
- Permanent establishment of the measures introduced to achieve sustainable groundwater protection.

The Lower Saxony cooperation model has created essential preconditions for the implementation of the above-mentioned objectives. In many cases, however, efficient implementation of groundwater protection measures cannot be achieved solely through cooperation with agriculture and forestry, but requires the inclusion of far-reaching nature conservation measures.

Reactivation of wetlands

Lowland soils originally close to groundwater often have large natural nitrogen reserves in the form of fen peat or humus-rich mineral soil horizons. Groundwater subsidence due to drainage measures or groundwater abstraction accelerates the mineralisation of the organic substance and thus releases nitrogen. This process can be accelerated by agricultural land use. For this reason, nitrate concentrations of up to 300 mg NO_3/l are measured in the leachate of fen soils or at the groundwater surface. The main concern of groundwater protection-oriented reactivation of wetlands is the prevention of such "nitrate breakthroughs" into groundwater. The measures for this concern the control of the groundwater balance and agricultural land use:

- In order to ensure low nitrate emissions from low moor soils, the groundwater level must ensure at least one year-round groundwater connection of the peat or bog body.
- Soil tillage and liming of soil with high humus contents that was originally near groundwater should be reduced to a minimum.
- The optimum use of such land is permanent grassland. The regulation of groundwater levels across all areas requires planning for the entire area.

Performance measurement

The reactivation of wetlands is particularly effective in the presence of mineralization-intensive low moorland peat that is countering a strongly increased release of nitrate due to drainage. With sufficient groundwater retention, nitrate leaching can even be reduced to zero. This requires that the groundwater can be raised all year round to the base of the peat body. Such a measure is usually only possible in purely grassland areas.

5.4 Biodiversity

Felicitas Kaemena (LWK) and Leanne Aantjes (Aeres)

Sources: https://www.eea.europa.eu//publications/eu-2010-biodiversity-baseline-revision

Grasslands are areas covered by grass-dominated vegetation with little or no tree cover. Various types of grasslands exist in Europe: from desert-like in the south-east of Spain, through steppes and dry grasslands, on to humid and generally damper grasslands and meadows, often on deeper and more fertile soils, lowland and mountain, which dominate in the north and north-west (EC, 2008).

Most European grasslands can be defined as 'semi-natural' because they have developed through natural processes over long periods of grazing by domestic stock, cutting and even deliberate light burning regimes; others may have originated from sown and grass leys aimed at producing forage for livestock. In almost all cases, they are modified and maintained by human activities, mainly through grazing and/or cutting regimes (Turbé *et al*., 2010). In this section, the term 'grasslands' includes meadows, steppes and grasslands managed (grazing, cutting, burning) with variable intensity. There is a large overlap with agro-ecosystems, which are covered in the corresponding section.

Change in grassland ecosystem areas since 1990 ([15])

Table 4.1 Surface area (km^2) of grassland ecosystem in 1990, 2000 and 2006

	1990	2000	2006
Pastures	292 264	290 903	289 711
Natural grasslands	77 308	75 795	75 514
Total	**369 572**	**366 697**	**365 224**

- In 2006, the total grassland ecosystem area was 365 000 km^2: 79 % pasture; the remaining 21 %, natural grasslands.
- In 2006, the total grassland ecosystem area was just over 1 % smaller than in 1990 for the same geographical area.
- In 2006, for the same geographical area as surveyed in 1990, pasture had decreased by 0.9 % and natural grassland by 2.4 %.

Note: Geographical coverage: EU except Greece, Finland, Sweden and the United Kingdom.

Source: Corine land cover.

Introduction

Biodiversity includes all living organisms found on land and in water. All those living organisms have a role in the 'fabric of life'. All the species, from the smallest bacteria in the soil, to the largest whale in the ocean. Biodiversity consist of four basic building blocks.

The four basic building blocks of biodiversity are genes, species, habitats and ecosystems (see textbox).

Genes. Genes are the basic building blocks of life. They determine the characteristics of all living organisms. Maintaining genetic diversity by conserving species and varieties is a cornerstone of nature conservation.

Species. Nearly two million species have been identified worldwide and it is estimated that these may represent only 20 % of the total currently existing on Earth. Soils alone host over one quarter of all species. Apart from micro-organisms, insects are the biggest and most varied group. Other large groups include fungi, plants, lichens and mosses. Compared to other continents, Europe and the EU have a relatively few species, although many are only present in the region (i.e. they are endemic).

Habitats. Different species of plant and animal come together to form ecological communities in a given area or natural environment called habitats. A habitat includes physical factors such as soil, moisture, temperature and light. Habitats are formed in response to local environmental conditions such as soil type and climate. In Europe, human activities have played a major part in shaping and creating habitats that are of high biodiversity value (e.g. meadows).

Ecosystems. An ecosystem can include one or many different habitats. Healthy ecosystems help to maintain species and habitats as well as providing critical 'goods and services' to human

The distribution of wildlife and the variety of landscapes in Europe are the product of complex interactions. The basic physical qualities of the rock, soil and climate provide underlying structure and continuing influence. But the majority of the detail has been shaped through millennia of natural processes and human activity, the history of land use and management and its associated impacts. Human activities are themselves driven by economic, social, and environmental forces.

As a result of these interactions, which are particular to Europe, 'multifunctional landscapes' have developed in which traditional cultural practices sustain a range of economic, social and environmental services. Among many of those multifunctional landscapes exist also pastures and natural grassland. Due to human activities, the biodiversity on those agricultural landscapes is under pressure.

<u>Status and trends</u>

The serious and continuing loss of Europe's biodiversity reflects the continuing decline in the ability of ecosystems to sustain their natural production capacity and perform regulating functions. For instance, healthy soil biodiversity is fundamental to maintaining and ensuring soil fertility and therefore production potential. The Secretariat to the Convention on Biological Diversity (CBD) has observed:

'The loss of biodiversity often reduces the productivity of ecosystems, thereby shrinking nature's basket of goods and services, from which we constantly draw. It destabilizes ecosystems, and weakens their ability to deal with natural disasters such as floods, droughts, and hurricanes, and with human-caused stresses, such as pollution and climate change. Already, we are spending huge sums in response to flood and storm damage exacerbated by deforestation; such damage is expected to increase due to global warming' (CBD, 2010).

Grasslands are among the most species-rich vegetation types (up to 80 plant species/m^2) in Europe and have great conservation value (Eriksson *et al*., 2002; Poschlod and Wallis de Vries, 2002; Wallis de Vries *et al*., 2002, in Vandewalle *et al*., 2010). There are different types of meadow habitats: natural, semi-natural, calcareous, dry, mesophile and humid; this reflects the high diversity of grasslands. Most of these, have been created, modified or maintained by agricultural activities.

Large areas of grassland have been lost in recent decades, causing severe fragmentation of the remaining habitat areas and a consequent drop in populations of certain species by as much as 20–50 % across Europe (EC, 2008). Grasslands are key habitats for many species: plants, butterflies, reptiles and many birds as well as grazing mammals such as deer and rodents. The grassland production plant biodiversity is already mentioned in previous chapters. Therefore, in this chapter, we are going to focus on the animal biodiversity, in particular meadow birds and butterflies.

<u>Meadow birds</u>

Meadow birds have their origins in steppes of savannah from outside Europe. However, they like the open grassland areas and have made grasslands their home. The general view over all countries is that the amount of meadow birds decreases as shown in the figure. (source: http://www.birdnumbers2016.de/downloads/ birdnumbers2016_example_manuscript.pdf)

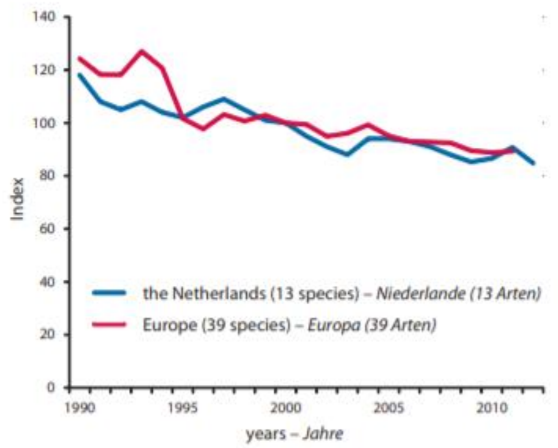


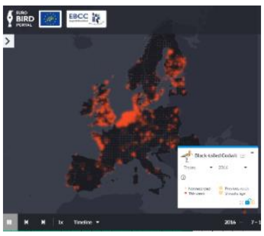
Fig. 2: Farmland bird index for Europe (39 species) and The Netherlands (13 species). The index is set to 100 in year 2000. Source: The Breeding Bird Monitoring Program (organised by SOVON in close collaboration with Statistics Netherlands and provinces and funded by the Dutch Ministry of EZ), European Bird Census Council (EBCC). –*Entwicklung der Bestandsindizes für Vögel der Agrarlandschaft in Europa (39 Arten) und der Niederlande (13 Arten). Im Jahr 2000 steht der Index bei 100.*

Most populations are in heavy decline due to intensification of agricultural management and higher predation pressure. Intensification of agricultural management are for example:

- Lowering of water tables for good horticultural circumstances
- Larger machinery
- More mowing on same dates

This is related to changes in land use and landscape http://www.altwym.nl/en.php/project/ ecological-monitoring/meadow-bird-ecology/

Large breeding populations of Black-tailed Godwit, Lapwing, Redshank and Oystercatcher are still present next to several other species. The status of birds per country are available on the website of the European Birds Census Counsil by the following link. http://www.ebcc.info/status-of-common-bird-monitoring-and-atlas-workin-single-states/



There is also a webpage available with a track and trace option of a lot of bird populations throughout Europe. This Euro Bird Portal is available via https://www.eurobirdportal.org/ebp/en/

Eighty-nine of the 152 grassland bird species (59 %) have an unfavourable conservation status in Europe (Birdlife International in Veen *et al*., 2009). This is a slight deterioration compared to a decade ago, when 81 grassland species had an unfavourable conservation status. A number of the now threatened species were formerly common in Europe: such as the lapwing (*Vanellus vanellus*), European starling (*Sturnus vulgaris*) and corn bunting (*Miliaria calandra*) (Tucker and Heath, 1994, in Veen *et al*., 2009). For young farmers it is important to find out which species are threatened in their country and how they can help them.

Butterflies

Butterflies are special animals. They transform in their lifecycle from eggs, to a caterpillar (larve) to a pupa and then to a butterfly. Therefore a butterfly needs different circumstances in their living area. Diversity of vegetation is the key for the butterfly. Flowers are also important for butterflies to survive because they drink the nectar of the flowers. The caterpillars of meadow butterflies mainly eat grasses and clovers.

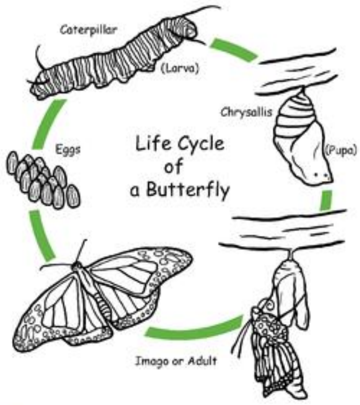


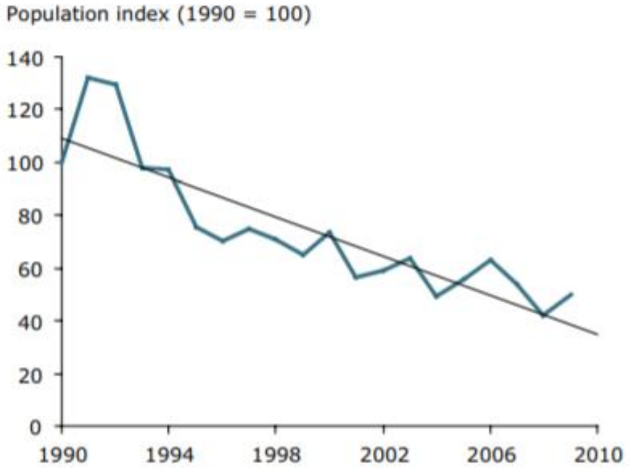
Figure 1. Lifecycle butterfly https://www.education.com/lesson-plan/life-cycle-of-a-butterfly/

To prevent predation it is needed to have some bushes and vegetation between 1 -1.5 meter high as a shelter. Besides that, the butterflies like high temperature, so they like sunny, open spaces where the wind doesn't blow. It is important to create these spaces in our grasslands.

Europe's grassland butterflies have declined by 60% since 1990 and this reduction shows no sign yet of levelling off (EEA, 2009). Intensification in use and production across the relatively flat areas of Europe is the most important threat to butterflies.

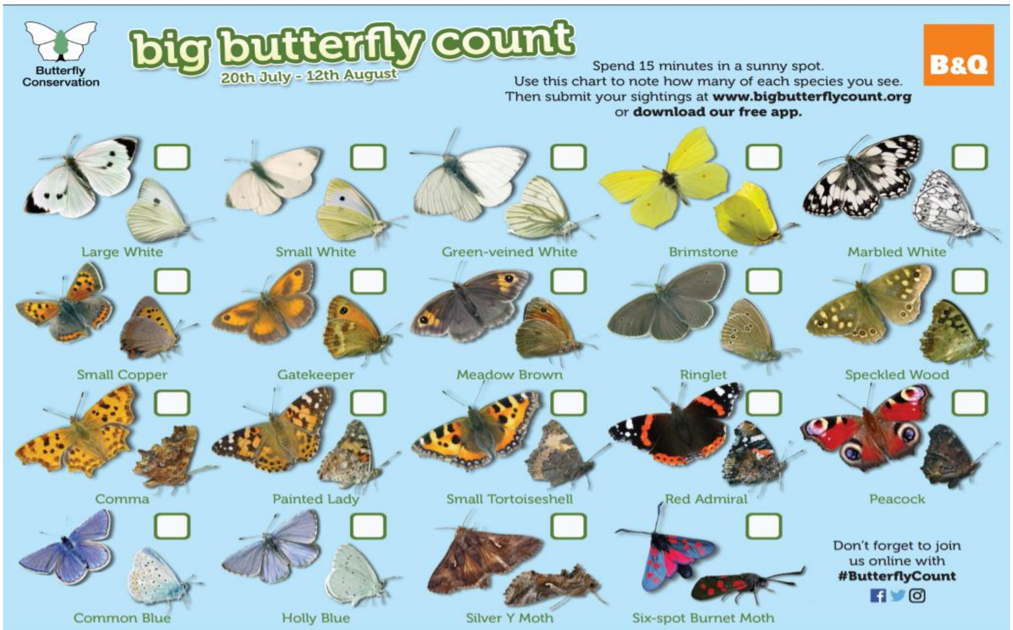
For the yearly butterfly count, several documents are available per country. In the figure below, you see the UK version.

Figure 4.5 Grassland butterflies, population index (1990 = 100)



Source: De Vlinderstichting/Butterfly Conservation Europe/Statistics Nederlands, 2010; SEBI indicators, 2010 — SEBI indicator 1.

The Dutch butterfly chart is free to download on https://assets.vlinderstichting.nl/docs/27cfc0c3-f9df-4ff9-9440-6d0ab3575eaa.pdf



An example: biodiversity in Germany

Of the endangered species of ferns and flowering plants in Germany, about 40 % grow mainly in grassland. The dramatic decline in the number of species of wild bees and butterflies is directly related to the reduction in species-rich grasslands. The overwhelming significance of the species-rich grassland in water, soil and climate protection is often overlooked. A high diversity of grasses and herbs has a proven positive effect on groundwater quality and the storage capacity of carbon in the soil. In fact, our grassland areas are the second most important carbon sink after the marshlands, making the preservation of species-rich historical meadows and pastures hugely important for climate protection.

In recent years, there has been a dramatic reduction in species-rich grassland areas. A distinction can be drawn between the loss of permanent grassland in itself and the decline in the proportion of species-rich grassland areas. The most important causes for the reduction in the proportion of permanent grasslands from the agricultural land areas are the intensification of agriculture, especially milk and meat production, as well as the increased cultivation of energy crops (especially corn) for biomass production. In the low mountain regions, the abandonment of grasslands also plays an important role. The deterioration in the quality of species-rich grassland (loss of species) observed in many places is also related to changes in agriculture.
The palpable changes in the growing season as a result of climate change has also left its mark on the grasslands, as these changes impact the less-competitive species first and foremost.

Grasslands are indispensable components in multi-functional agriculture, and not only for agricultural production. They also have tremendous value for biodiversity, as recreational areas for the local population, and for a multitude of nature conservation and environmental concerns.

No other part of the world has such a wide variety of cultivated grassland ecosystems (Dierschke & Briemle 2002). Certain long-standing, extensively-used types of grasslands, such as the limestone grasslands, are among the most species-rich biotopes in Central Europe. A third of all indigenous ferns and flowering plants grow mainly in the grasslands (1,250 of 2,997 species assessed as belonging to a vegetation unit and as endangered). Of the endangered species of ferns and flowering plants in Germany, around 40 % (or 822 species) are found in grasslands. Grassland had its greatest diversity of species and communities in times of semi-extensive to semi-intensive land use, i.e. mainly from the 18th to the middle of the 20th century (Dierschke & Briemle 2002).

With its diversity of structures and seasonal flowering sequences, grassland provides a habitat for a great variety of animals, ranging from vertebrates such as birds and amphibians to the micro-organisms of flowers and inflorescences, with very close interrelations between flora and fauna (cf. Dierschke & Briemle 2002). Due to the enormous species spectrum and the large number of different sites, the conservation of grassland plays an essential role in achieving national, European and international biodiversity goals.

The bird population in the cultivated areas in Germany is coming under increasing pressure – in the agricultural areas, the number of birds has halved over the last thirty years. According to the results of the 2013 national bird protection report, the number of species with declines in the 12-year period has increased significantly compared to the 25-year period: over the short-term period, a third of all breeding bird species (84 species) show significant declines. The largest percentage of declining populations is accounted for by species in the open land and settlement areas.

Photo: Lapwing breeds in open, flat landscapes and prefers short grass

Most bird species that breed on fields, meadows and pastures are clearly declining in numbers due to the high intensity of agricultural activity. In species such as the lapwing and the black-tailed godwit, which breed predominantly in wet meadows on the ground, population losses have persisted for decades. The population of the lapwing has shrunk to a quarter of what it was over the last 20 years, while that of the black-tailed godwit has halved. During the same period, both species also show declining populations throughout Europe.

The agricultural areas in Europe have now lost about half of their birds. In total, 300 million fewer birds than merely 30 years ago live in the open cultivated area of the European Union today. The European Farmland Bird Index has also fallen by more than 50 percent since 1980. The most important causes for the threat to important bird species are the loss of breeding and food habitats due to increasingly intensive agriculture and the drainage of agricultural land. The tillage and drainage of grassland have significantly reduced the area of habitat for breeding birds in wet meadows. The conversion of meadows and pastures into arable land for the cultivation of bioenergy crops has drastically aggravated the situation in recent years.

Photo: The dusky large blue is dependent on grassland areas with burnet

With the decline in grassland, insects such as bees and butterflies, which depend on an abundant supply of flowers and nectar, lose their food source and habitat. The current red list of invertebrates (Binot-Hafke *et al*., 2011) shows that the downward population trend has continued, in particular, for butterfly species found on alkaline grasslands and dry grasslands and bees found in hay meadows, alkaline grasslands and heaths. In addition, there is the loss of ecotone in the agricultural areas, which directly harms small mammal and amphibian (e.g. common frogs) populations in wet grassland and the populations of species in or in contact with fresh and dry grassland, such as the endangered common hamster and the sand lizard. In the current Red Lists (Binot-Hafke *et al*., 2011), species linked to habitats rich in small structures, such as orchards, also show downward trends (e.g. bees, ants).

Grassland areas with rich biodiversity are the habitat for numerous endangered animal and plant species.

6. Quality of product from grass

The text below is based on *Couvreur S et al., Les Prairies au service de l'Elevage - Comprendre, gérer et valoriser les prairies, 2018*

Milk and dairy products quality

Dairy product quality is highly dependent on the initial composition of the milk and on the same factors of variation on the farm than the milk itself. Milk quality depends on many factors: species, breed, stage of lactation, sanitary state of the animal and feeding. When feeding is based on grazed grasslands or grass-based forage, the useful components of the milk change: proteins and fat matter, but also fatty acids, vitamins, pigments, phenolic compound and terpenes. The effect of grass-based feeding on milk quality particularly depends on how it is brought (grazed grass or conserved forage), how much it contributes to the whole ration, its vegetative stage, its botanical composition and its supplementation.

Effect of grazed grass on milk composition

Compared to maize, grazed grass is very rich in soluble sugars, in α-linoleic acid (C18:3n-3)-riched lipids (linoleic acide or C18:2n-6 for corn) and in minor components (pigments, vitamins and terpenes) whose quantity varies depending on the botanical richness. This difference in composition has a big impact on milk composition.

For example, an exclusively spring grass based ration, compared to maize, equals:

- A maintained or slight increased protein level and, more often a decreased fat level. However, fat level increases when the diet is exclusively based on pasture compared to pasture and concentrates. A variation in fatty acids:
    - Saturated fatty acid level decreases. The effects are stronger for cow milk than for sheep milk and finally for goat milk;
    - C18:2n-6 level decreases while C18:1cis9 and C18:3n-3 levels increase with the same variation between species as mentioned above;
    - Total "trans" fatty acid levels increase in cow and sheep milk, while they do not vary much in goat milk. This can be explained thanks to differences in metabolism but also because rations contain high grass-based conserved forage levels and lipid supplementations.
- A variation in pigments and vitamins levels:
    - B-carotene levels (pigment, precursor to vitamin A synthesis) increase but only in cow milk
    - Vitamin A and E levels increase in cow, sheep and goat milk
    - Vitamin B12 level decreases
    - Vitamin B2 and B9 levels increase
- An increase in phenolic compounds and terpenes levels.

These variations will be more or less important depending on the grass species and the vegetation stage of the grassland. The more diverse the botanic composition (legumes, herbs) is, the more important the effects on the phenolic compounds and terpenes levels are. The later the vegetative stage is, the more mitigated the effects on fat and protein, fatty acids, pigments and vitamin A composition are, depending on the different leaves and stem quantities. Finally, the grazing management also impacts the milk composition. When grazing managements favour a quantity and quality-regular grass consumption, greater variations appears on fatty acids levels. When grazing managements are more rationed out with high stocking rates on diversified grassland, terpenes levels could be higher. For cows, increase in grass part in a ration based on corn silage will equal to a decrease of fat, an increase of protein up to a threshold and a modification of fatty acids composition.

Effect of the grass conservation type on milk composition

The forage composition depends on the methods of harvesting and preserving the grass, that affect milk composition. The effects of forages on milk fat and protein composition, on fatty acid profiles and on pigments and carotene contents, are less and less strong in the following order: grazed grass > fresh grass to the trough > hay > grass silage > grass haylage. The order could sometimes be different depending on the harvesting conditions of the concerned forages. Forages conserved with much diversified composition regarding botanical aspects still remain rich enough to have effect on the phenolic compounds and terpene levels.

Dairy products quality

Dairy products are transformed from milk. Their quality is defined regarding the following characteristics:

- Organoleptic (texture, taste, flavors, color, etc.);
- Nutritional;
- Technological (yield);
- Functional (spreadability, melting, flowing, etc.).

Grass-based diets, that modify the fat, vitamins, pigments, phenolic compounds and terpenes composition of the milk, have comparable effects for butter and cheeses.

- The butter (spreadability and melting) and cheese texture at a given temperature is explained by the ratio of solid to liquid fat. This ratio varies according to the fatty acid composition, and depends in particular on the two majorities: C16: 0 (which has a firming effect) and C18: 1cis9 (which has a softening effect). Thus, grass-based diet, by increasing C18:1cis9 content and decreasing C16:0 content increases the spreadability and melting in the mouth compared to corn silage-based diets. As soon as there is more than 60% of spring grass brought to the trough, this effect becomes significant. The more grass has been produced at a leafy stage, the greater the effect on the texture.

- The color of butter and cheese is directly related to the β-carotene content. Compared to corn silage, the grass is richer in carotenoids and therefore produces more yellow products, only for cow's milk products. In the production of preserved grass forages, the drying time on the ground reduces the pigment content. The effects of forages on the color are less and less strong according to the following order: grazed spring grass > grazed grass in summer (bushy) > ventilated hay > grass silage > haylage > hay dried on the ground.

- The flavor of butter and cheese is the result of many interactions between the initial composition of milk and its evolution during processing and ripening. Compared to hay, grass gives a stronger taste to the products. The presence of natural antioxidants from grassland (vitamin A and E) decreases the oxidation defect on taste: metallic or fish taste. As for other quality characteristics, these effects are greater when grass is brought fresh, leafy and in large quantity in the ration.

Meat quality

The diet management and the nature of the feed have varying effects on the organoleptic and nutritional quality of the meat. The nature of the feed has little effect on the tenderness of beef (pasture, forage kept dry or wet). In sheep production, fattening systems (on grass or in buildings) have no significant effect on the tenderness of the meat either. Livestock farming practices regarding grazing management in cattle and sheep do not have an impact on the juiciness of the meat.

A finishing of sheep and cattle on the grass changes the flavor of the meat. This is explained by the differences in fatty acid profiles induced by the presence of grass in the ration (a phenomenon comparable to what has been described for the composition of milk). During cooking, fatty acids produce different volatile compounds that cause the "pastoral" flavor of meat.

Pasture feeding has an effect on the color and the fat of the meat. Cattle and sheep reared on the grass produce a darker and more red meat than animals rose in the trough (following photos), due to a higher content of a pigment called myoglobin. Also, the fat of sheep and cattle meat is more yellow (especially when grasslands are valued at the leafy stage) and is explained by a transfer to the adipose tissue of a larger amount of β-carotene ingested.

Comparison between carcasses from animals fed with grass (on the left) or with corn silage (on the right)

Grassland grazed or distributed in preserved forage improves the nutritional quality of the meat, in particular the fatty acid composition by increasing the levels of C183n-3, C18: 1trans11, C18: 2cis9trans and decreasing the saturated fatty acid contents. The nutritional quality is preserved thanks to the transfer of vitamin E from the grass by protecting the interesting fatty acids from being oxidized.

<u>Example: Testimony from a farmer – GAEC des Violettes (Puy-de-Dôme, France) – effect of grassland use on cheese</u>

On this farm of 57 ha of permanent grasslands, located at 1,000 m altitude, 47 dairy cows of Montbéliarde and Abondance breeds are milked. The milk is transformed into Saint-Nectaire on the farm. Calving period extends throughout the year to ensure regular cheese production and sale. The ration of the dairy cow is based on grass, grazing from spring to autumn and with preserved forages (hay / leftovers) in winter. Concentrates are distributed during the year but never beyond 230 g/L of milk. The farmer uses rotational grazing and changes plots every three days. A hay supply is maintained throughout the year, but its consumption is very low during the grazing period.

Farmer's look	Cheesemaker's look
Longer transitions to manage the cheeseability of the milk	
"As we make cheese, we pay close attention to transitions! Before, we made abrupt transitions and we needed a perfect mastery and adaptation of the cheese technology. To avoid this, we now make long transitions. When we turn the cows out for grazing or back into the barn, we make a one month-transition, approximately. When we change a feed, the transition is also long to limit the sudden changes in the quality of the milk."	"When we turn the cows out for grazing, the grass is rich and the vegetation optimal. Rates increase at this time. In terms of cheese processing, care must be taken to squeeze the cheese to prevent it from crashing. We need to be very reactive because problems can appear 2-3 weeks later and it then impacts several fabrications. When we turn the cows back into the barn, it's the opposite. The milk being less rich, we must be careful not to over-tighten the cheeses".
A supply of hay during the grazing period to better manage the cheesability	
"In addition to paying attention to the transitions, I always leave a little hay in the summer to stabilize the belly."	"The all year-supply of hay, and therefore a little fiber, allows to have less fits and starts on cheeses. During the grazing period, the plot changes to the amount of milk to be processed. At the end of grazing of a parcel, the quantity of milk decreases: the vat of milk is thus less filled which makes the transformation difficult. Indeed, below a filling of the tank to 3/4, the transformation is more difficult.

Overall effect of the use of grass in the ration on cheeses	
“As we make cheese, we mainly look at the rates (fat and protein rates) more than the quantity of milk! We work with what forage and grass we have: we must adapt to the available grass, especially with permanent grasslands. We see many differences on the milk (in quantity) according to the grasslands but the cheesemaker adapts himself. Overall we warn each other when there are changes.”	“Feed has an effect on cheeses: in winter the dough is whiter and in summer it is more yellow. The flavors will change too. The grass brings the typicality to the product! The transformation with grass is more complex but it is our image and the cheeses are tastier! And if we anticipate and adapt, everything goes well. We work with the living: it moves all the time.”

7. Characteristics of individual countries

7.1 Sweden

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Introduction
In Sweden, short-term leys incorporated into arable crop rotations are the main forage crop, unlike the perennial forage swards farther south in Europe. Short-term leys and green fodder crops are the most widely grown crop type in Sweden (43% of arable land in 2017). In a wider perspective, including semi-natural grasslands, 51% of agricultural land in covered by grass. Due to the increasing price of concentrate, having regionally produced high-quality fodder is of fundamental importance for most producers. Perennial crops have a number of positive environmental effects in terms of decreasing nitrate leaching and nitrous gases, increasing carbon sequestration, improving soil structure and crop rotations etc. Swedish silage-based production and utilisation has been described previously (Spörndly & Nilsdotter-Linde, 2011). Here we provide a rewritten and updated description, including developments during recent years.

Climate conditions for grass and legumes in Sweden
Growth and development are influenced by temperature and light (light intensity and day length). The combination of temperature, insolation and day length is unique in Scandinavia/Fennoscandia and neighbouring parts of Russia. Insolation is not a limiting factor for growth, since most crops are C_3-plants. The temperature conditions are favourable in Scandinavia despite its northerly position, with all the Nordic countries except southern Denmark being above 55°N. Three Nordic capitals, Helsinki, Stockholm and Oslo, are located at roughly the same latitude as Anchorage, Alaska. However, thanks to the Gulf Stream, especially influencing winter temperatures, the climate is temperate, with a combination of favourable summer temperatures and long days. Despite the relatively low sun height, total global insolation is high due to the long day length.

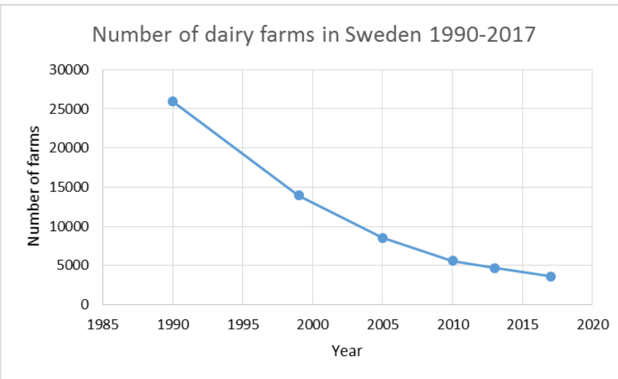
Given the short growing season (day and night mean temperature >5°C), which ranges from 150 days in the far north to 240 days in southern coastal areas, the grazing season in Sweden is short and conserved forage on an annual basis accounts for about 50% of the total dairy cow ration, while the corresponding figure for pasture is only approximately 10%. However, for beef cattle, growing heifers and sheep, silage is generally the main feed in winter and pasture is the main feed in summer, when grazing is possible for 3-5 months depending on geographical location. In a change during recent years, an increasing number of horses are now fed silage and many horses are kept on pasture in summer.

Feeding ruminants and horses up to the 1960s

The grazing season in Sweden is May-October in the south and June-August in the north. Traditionally, grazing was concentrated to areas not suitable for ploughing and cropping. Due to the accumulation of water and nutrients in the soil after 6-9 months of winter and the long daylight periods in the spring (17 h in the south and 22 h in the north on 1 June), the grass growth rate is much faster in the early growing season. Therefore, in the past suitable grassland areas were excluded from grazing and used for production of hay for the coming winter. Hay was cut as a single cut in the end of June in the south and one month later in the north. The area was then used for grazing later on in the summer, when the decreasing growth rate required extended areas for grazing.

Hay making was a time-consuming process that included cutting, raking, filling hay racks and finally transport to the hay barn. This produced a feed adequate for horses in moderate work or very low-producing dairy cows. However, supplementation with some concentrates were always needed. Barley and oats were usually grown for this purpose. Faba beans were sometimes used as a protein supplement but, in the 1950s, imported protein sources such as coconut cake, groundnut cake, cottonseed cake and soybean meal became very common.

From the 1950s on, the Swedish state invested great resources in rationalising agricultural production. The main goal was to decrease the need for labour on farms in order to supply the fast-growing industries with more labour. In the 1960s, this resulted in farm mechanisation and amalgamation, and the number of farms decreased from over 200 000 dairy farms in 1960 to less than 85 000 in 1970. The decline in number of farms continues and number of dairy farms is now down at 3600, as can be seen in Figure 1. However, total milk production in Sweden decreased by only 10% in the past 25 years, due to larger farms and higher yield per cow.



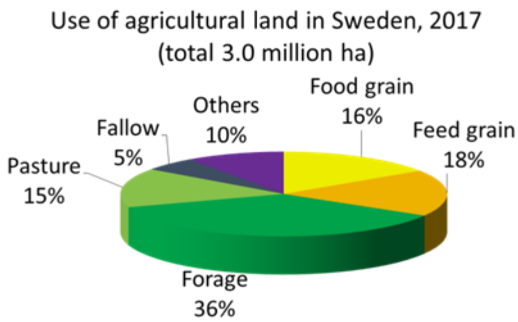


Figure 1. Number of dairy farms in Sweden 1990-2017 (left) and use of agricultural land in Sweden 2017 (right) (Swedish Board of Agriculture, 2018a).

Use of pasture – historical development
Historically, pasture was an important feed asset and cattle, sheep and horses were kept in wooded areas or on non-cultivated pastures in summer. As productivity increased with mechanisation and the introduction of mineral fertilisers, the most productive animals, such as dairy cows, were gradually moved to temporary grasslands near the milking parlour and growing stock was kept on semi-natural pastures. When interest in biodiversity started to increase in the 1970s, the importance of semi-natural pastures for biodiversity was recognised and the first subsidies to maintain the biodiversity values of these pastures were launched. These subsidies were gradually expanded and are now an important part of the production system for rearing heifers, steers, suckler cows with offspring and sheep.

In conjunction with the increase in farm size and the rationalisation of milk production that took place the 1960s and 1970s, grazing of dairy cows in particular started to decrease. This was especially apparent in northern parts of Sweden, where advisory organisations started to recommend that farmers abandon outdoor grazing and turn to year-round indoor feeding of dairy cows. This was mainly due to the short grazing season in the region, combined with increasing farm size and higher levels of milk production. Efforts to organise grazing for large herds were not regarded as worthwhile or economical for the short grazing season, which sometimes lasts only two months. This practice started to spread southwards and gain certain acceptance. However, in the late 1970s a discussion started among farmers, the advisory system and the general public about production conditions in relation to animal welfare considerations. This attracted great interest among the public and resulted in new legislation to promote animal welfare on farms. Thus, in 1980 a law was passed stipulating that animals must be given the opportunity to express their natural behaviour, which for cattle, sheep and goats meant that they had to be given the opportunity to graze outdoors in summer. With the exception of bulls and calves younger than 6 months, the law required non-lactating cattle and sheep to be on pasture 24 h per day. For dairy cows, the law initially required that they should be put to pasture between two milkings. However, since the law was launched in 1980, the requirements have been adapted to new production conditions such as the introduction of automatic milking. However, although the law has been slightly modified on several occasions, the basic requirement still remains (Swedish Board of Agriculture 2016): that cattle and sheep should be given the opportunity to graze during the summer period.

Comparative studies of hay and silage in the 1970s
Total annual milk production remained about the same, 3 million tonnes, from 1960 to 2000. However, the drastic decrease in the number of farms during the 1960s temporarily resulted in a smaller total amount of milk produced, which promoted intense research during the 1970s to increase production, in order to secure self-sufficiency of milk in the country. One of the main changes in cultivation during this time was that forage cultivation for winter feed moved from grazing areas to arable land with higher potential. This was necessary to keep winter feed production near the growing herd, and was possible because of increased crop yield brought about by mineral fertilisation.

In the 1970s, great efforts were made at the Swedish University of Agricultural Sciences (SLU) to study the effects of conservation method and stage of silage/hay maturity when fed to dairy cows. Cuts at different stages of development and silage with or without wilting were also studied (Bertilsson, 1983). The studies concluded that silage gave more milk than hay. In one three-year experiment where 131 cows were given hay or silage in equal restricted amounts, the silage-fed cows produced 4-10% more milk. When harvest was postponed by 10-20 days, hay gave an 8-10% decrease in milk yield, while silage gave a minor decrease (Table 1).

The silage system displayed many other benefits in practice, e.g. it needed a shorter period of dry weather and resulted in lower field losses than haymaking. Since farm size had grown, the traditional hay racks were abolished in favour of field curing, which was easier to mechanise. However, when the dry hay was pressed in the field, many the finer parts of clover and grass plants were over-dried and became brittle and were lost, resulting in a lower energy and protein concentration in the hay, although it was cut on the same day as the corresponding silage. These field losses were accounted for in an experiment where the hay was harvested at 60% dry matter (DM) and then dried further in the barn (Table 1). However, in practice the hay was dried to higher DM levels when the weather was good.

The studies at SLU had a great impact on a dairy business that was declining and in great need of methods to increase production.

Table 1. Daily feed data intake and animal performance data. Early cut at booting stage and late cut 10 days later. Three-year ley fertilised with 89 kg N, species timothy, meadow fescue and red clover. Hay wilted to 60% in the field and to 87% DM in barn drying. Silage direct-cut, 26% DM. Forage fed restricted, concentrate according to milk yield. Lactation week 2–10, year 1. (From Bertilsson, 1983)

	Early cut hay	Early cut silage	Late cut silage
Forage intake, kg DM day^{-1}	8.7^{a}	8.4^{b}	8.5^{b}
Concentrate intake, kg DM day^{-1}	8.1	8.4	8.6
Energy intake, MJ day^{-1}	197	199	194
Milk production, kg day^{-1}	26.1^{a}	27.4^{b}	26.2^{a}
Milk fat content, %	4.56	4.65	4.57
Fat-corrected milk, kg ECM day^{-1}	28.6^{a}	30.5^{b}	28.3^{a}

Means with different superscripts within rows are significantly different at $P < 0.05$.

Conversion from hay to silage for dairy cows in the 1980s

The research findings from the 1970s and early 1980s were taken into practical use through the advisory organisations, facilitated by the fact that the number of dairy farms was decreasing rapidly and that the farmers were members of various cooperative advisory organisations. About 90% of dairy cows were included in the milk recording system organised by the Swedish Dairy Association, which also organised artificial insemination. Cows were test-milked once a month, the data were collected in a national database and most farmers had the feed ration recalculated to each individual cow after each test milking, based on the latest yield and the feeds available at the farm. This system required feed analysis of the roughage produced on the farm. Thanks to this system, farmers became aware that a higher nutrient content in their home-grown forage immediately resulted in a ration that contained less commercial concentrate, which meant less cash outflow from the farm.

Experiments had shown that the silage system gave lower field losses and higher nutrient concentration in the forage than the hay system when harvested at the same time. Although the difference was not so great as to be obvious in practice, the old tradition of harvesting the hay at a late stage of development gave the new system an advantage. When silage making was introduced, it was made clear that it had to be harvested in the grass booting stage and it soon became obvious that silage always had a higher protein and energy content than hay.

Decrease in roughage in the dairy cow diet in 1990s and increase in 2000s

In the early 1990s, the transition from hay to silage was almost complete in the dairy business. The production per cow increased with the shift to silage and in 1990 cows were producing 7100 kg milk per cow per year, compared with 5900 kg in 1980. After having achieved the positive response in milk production by changing to silage, the quest for larger production continued. The price ratio between concentrate and milk was such that it was profitable to increase concentrate to get more milk per cow. A summary of how high-producing cows were fed in Sweden from the mid-1970s until today gives an idea of how the feeding practice developed (Table 2). In the example, the shift to silage and better forage quality was made between 1975 and 1982. Thereafter, the concentrate proportion increased steadily until some years into the new century. The reason why this was possible without negative consequences on animal health was the composition of the concentrates. The starch proportion was not allowed to increase to harmful levels and the cereals were successively replaced with fibre in the form of sugar beet pulp and other fibrous products. The amount of grain per cow remained at approximately the same level from 1986 and 2015 The trend towards larger concentrate amounts was broken some years ago due to concentrate becoming too expensive in comparison with high-quality forage. This is why silage is coming back in the dairy ration, even for high-producing cows. In 2017, annual milk production per Swedish cow in official milk recording exceeded 10 000 kg energy-corrected milk (ECM).

Table 2. Historical overview of winter feeding of high-yielding dairy cows in practice in Sweden

Year	Feed ration	Milk yield per cow/year (kg)
1975	7 kg hay + 10 kg concentrate* (shift hay to silage)	5 500
1982	11 kg DM silage + 10 kg concentrate (75/10/15)*	6 200
1986	9 kg DM silage + 13 kg concentrate (60/20/20)*	6 700
1994	7 kg DM silage + 16 kg concentrate (50/30/20)*	7 600
2005	9 kg DM silage + 16 kg concentrate (50/30/20)*	8 500
2015	12 kg DM silage + 15 kg concentrate (50/30/20)*	10 000

* = grain/sugar beet pulp/oil seed cake (%).

Change to round bale silage among smallholders
Although silage was introduced as the forage conservation system on all dairy farms in the 1990s, a large proportion of the grassland was still harvested as hay. That was predominantly on smaller farms with beef cattle and, of course, as winter feed for the growing horse population. Beef in Sweden is mainly a by-product from the dairy herd. Male calves go to beef production and since the replacement percentage in the dairy herds is high, a great deal of beef also originates from cull cows of varying age. However, some production of specialist beef cattle takes place on small or medium-sized farms. The winter feeding season for this type of animal is shorter, lowering the quantity of conserved feed needed. It is always difficult to feed silage from a silo to few animals, since the low speed of use can easily lead to problems with heating of the silage. Farms handling few animals also have a low level of mechanisation and handling silage by hand is heavy work. However, turning to silage with larger nutrient content was attractive for beef farmers, who saw the possibility of raising the animals on forage only, without concentrate.

Farmers, always in the front line of development, tried their own way. Big round bale machines to harvest and store straw had become common among grain-producing farmers and were also used for hay in certain areas. The same farmers bought fertiliser in big plastic sacks. Some enterprising hay-producing farmers tried pressing wet grass instead of dry straw or hay in the bales, put them in the plastic fertiliser sacks and sealed them thoroughly – round bale silage was invented!

The idea spread and the round bale system was soon a subject for the research institutes. The initial finding from most studies was that round bales were not well suited for silage making. In relation to silos, the surface area is much larger and contact with the air tends to destroy the outer surface of all silage. Therefore, the expectation was for great losses in this system and also a lot of problems with unwanted microbial activity such as enterobacteria, clostridia, yeast and mould. Such problems were found, but to a lower extent than expected and with great variability, which indicated that the system could be improved.

After some years with round bales in sacks, stretch film was introduced for wrapping and became a major success. The laborious work of putting the bales in sacks was removed and the elastic layers of film worked as an ideal one-way valve, letting gases pass out of the bale but stopping air penetrating in. One of the major problems with the bales in sacks was that they blew up and were often punctured.

Trials soon reported good results with wrapped bales (Lingvall & Lindberg, 1989; Lingvall *et al*., 1990, 1993) and the system spread rapidly. A survey of silage systems in use in 17 European countries found that forage wagon and metered-chop systems were most common in almost all countries, but Luxembourg, Norway, Sweden, Switzerland, Italy and the UK reported that big balers were increasing (Wilkinson & Starke, 1992). In Sweden, big balers were non-existent in the 1980 statistics, but were the 5th most sold in 1985 and the 2nd most sold in 1990.

Finally, horse owners turn to silage
By the late 1990s, the only major category of grass consumers that were still on hay were horses. The horse population in Sweden has increased substantially in recent decades and horses now consume a great deal of the forage produced. Ensiling the

grass was reported to reduce voluntary intake in horses, and horse owners sometimes claimed that silage was refused by their horses. Since no real comparison had been made between hay and silage of the same crop, cut at the same time and in the same field, an experiment was set up in which wrapped forage with 35% DM (silage) and with 55% DM or 70% DM (haylage) were compared with hay with 87% DM (Müller & Udén, 2007). When horses were presented with these feeds in a free choice system, silage was the first choice in 85% of observations and had the highest consumption rate. Hay had the lowest consumption rate and was never completely eaten. The haylages fell in intermediate order, with the drier types less popular. The conclusion was clear; horses like silage and haylage better than hay.

Other experiments dealt with different additives and DM levels (Müller, 2005). The silage was made using a conventional high-density hay baler that produced square bales with dimensions 80 cm × 48 cm × 36 cm. The idea was to produce silage that was easy to handle in horse stables and thus attractive to horse owners.

Recent studies comparing DM losses involved with different silo systems for silage resulted in surprising differences between the large silo structures and the wrapped bales. In field studies on farms, constructed silos (bunker and tower) had 14.1% DM losses and bag silos had 11.5% DM losses, while wrapped forage bales had DM losses of only around 1% (Spörndly, 2017).

Altogether it is not surprising that more forage is preserved in wrapped bales in Sweden (about 50%) than in bunker, bag or tower silos (Pettersson *et al.*, 2009).

Grazing in Swedish production systems of today

Due to continuous investment by society in maintaining the biodiversity of semi-natural pastures, Sweden now has approximately 450 000 ha of semi-natural grasslands, many of them with high biodiversity values with regard to plants, insects, birds and other organisms. Beside the permanent semi-natural grasslands, there is approximately 170 000 ha of grazed temporary grassland in Sweden, as shown in Figure 2.

Although most grazed temporary grassland in Sweden consists of a mixture of species, e.g. meadow fescue, perennial ryegrass, smooth stalked meadow-grass and white clover, semi-natural pastures are even more heterogeneous. They consist of a mixture of dry, mesic and wet vegetation with a wide range of species. The proportions of these different types of vegetation vary between different pastures, depending on geographical location and soil conditions. The large difference in vegetation types also leads to a large variation in herbage production. Annual production of dry, mesic and wet vegetation in Swedish semi-natural pastures is reported to be approximately 1800, 3000 and 4400 kg DM per ha, respectively (Spörndly & Glimskär, 2018). In a similar manner, the forage nutritive value differs considerably, with the highest average annual content of metabolisable energy reported for mesic vegetation and the lowest for wet vegetation, according to weighted averages in recent studies (Spörndly & Glimskär, 2018). Furthermore, there are often considerable numbers of bushes in semi-natural pastures, often with thorns that animals will avoid, such as dog-rose and blackthorn. Trees are often larger, solitary trees such as larger birch and oak trees that provide shade for grazing animals.

Figure 2. Area of semi-natural grassland and grazed temporary grassland in Sweden, in 2017 (Swedish Board of Agriculture, 2017).

The semi-natural pastures are mainly grazed by cattle, with regard to acreage (Table 3), but also with regard to number of grazing sites and grazing animals according to a large inventory of a stratified sample of semi-natural grasslands (Spörndly & Glimskär, 2018). As shown in Table 3, cattle dominated the pastures in the inventory, grazing approximately 65% of the acreage and a similar proportion of sites. Cattle breeds grazing these semi-natural pastures are approximately 50% dairy breeds (Swedish Red breed or Swedish Holstein) and 50% beef breeds or crosses with beef breeds. Horses and sheep each graze approximately 10% of the area of semi-natural pastures and mixed herds with several animal species are also common, especially on larger sites. Approximately 40% of the sites in the inventory were small, 0-5 ha, but a few larger sites (5% >40 ha) constituted 40% of the total area studied (Spörndly & Glimskär, 2018). The large number of smaller sites is important with regard to maintaining biodiversity by facilitating the spread of plant species between different areas, while the larger sites play an important role in providing a large area with similar and stable biological conditions.

Table 3. Proportion of cattle, sheep and horses grazing semi-natural pastures in Sweden. N = 219 sites, with an average size of 14 ha. (Spörndly & Glimskär, 2018)

	% of acreage	% of grazing sites	% of grazing animals
Cattle	68	64	66
Horses	8	18	5.5
Sheep	9	11	28.5
Mixed[1]	15	7	

[1]Mainly cattle and sheep.

In contrast to semi-natural pastures, temporary grasslands are mainly grazed by cattle with higher nutrient demands, such as dairy cows. Under Swedish law, the required length of the grazing period depends on geographical location, ranging from 60 days in the north to 120 days in the south of Sweden. For all categories except lactating dairy cows, 24-hour grazing is required. For lactating dairy cows the daily grazing time is shorter, but they are required to come out to pasture daily and have access for at least 6 hours to a pasture area covered with vegetation that can be grazed simultaneously by all cows in the group. The amount of pasture that the animals are offered is not defined in the law, however. With increasing herd size and approximately one-third of all milk produced in automatic milking systems, the use of pasture as part of the diet has decreased substantially. Thus, many farmers provide their animals with a smaller grazing area with some opportunity to graze, primarily for welfare and recreation to fulfil the legal requirements. This system is often referred to as exercise pasture. Cows with access to exercise pasture are still offered full indoor feeding with concentrates and silage during most of the summer, to ensure that their nutrient needs are covered at all times. Swedish consumers have a keen interest in animal welfare and, in 2018, this led the largest dairy to introduce a price premium to farmers who allow their cows to have 25% longer access to pasture (i.e. 7.5 h) than the stipulated minimum 6 hours of access that the law requires (Arla, 2018). This, together with the comparatively low cost of pasture, may create increased interest in pasture as a feed for dairy cows in coming years.

Organic production in Sweden

In Sweden the organic production is increasing in all sectors. This is particularly pronounced in forage and cattle production. Table 4 summarises the extent of organic production 2017. In organic dairy production, the main organisation that certifies organic milk (KRAV, 2018) stipulates that pasture intake must be at least 6 kg DM daily. Furthermore, dairy cows must be kept on pasture for more than 12 hours daily, a major difference compared with conventional production.

Table 4. Organic production in proportion (%) of total agricultural land or animal stock (Swedish Board of Agriculture, 2018a)

Organic production	Proportion of total agricultural area or animal stock (%)
Total acreage	19.1
Cereal grain (wheat, barley, oats, rye, triticale)	9.5
Forage (legumes/grass, green fodder, ploughed)	22.1
Semi-natural pasture	24.6
Dairy cows	16.4
Beef cows	33.7
Sheep	20.9
Pigs	2.3
Leying hens	17.0
Broiler	1.9

How did the new conditions influence seed selection?

Forage species and varieties well adapted for different purposes and regions are crucial for high quality and quantity in forage production and thus beef/dairy farm profitability. The problem with introducing winter-hardy plant material from e.g. Canada into Sweden is that growth starts earlier in spring and stops later in autumn in Sweden than in Canada. It is necessary to breed and test plant material for Sweden, where SLU runs the official variety testing programme (VCU) (Halling & Larsson, 2017). The plant material mainly consists of Swedish-bred varieties. Lantmännen Lantbruk has active breeders of forage crops, e.g. timothy, meadow fescue, perennial ryegrass, cocksfoot, lucerne, red clover and white clover, but a great proportion of the forage seed sold comes from other countries validated for the EU list. Fortunately, most of these varieties are also validated for Swedish conditions.

Characteristics important in utilising inherent seasonal growing pattern, competitiveness, resistance to pests and winter hardiness of species/varieties include: role in cropping, grazing and feeding system; persistence; cutting regime; and fertilisation regime.

Since 2002, the amount of sown legumes in Swedish temporary grasslands has increased from 16.3% to 18.6% of the total amount of certified and imported seed of the main forage species for silage production (Swedish Board of Agriculture, 2018b) (Table 5). The ratio of different species has changed over time, with red clover having decreased and white clover and lucerne having increased. In recent years, there have been studies on fibre quality in timothy, leading to improved varieties and more sown timothy than before. There have also been some setbacks in the use of ryegrasses, as despite the nutritional advantages of these high-yielding grasses, the climate conditions in Sweden sometimes prevent efficient use of these species. Accordingly, the most winter-hardy forage grass, timothy, has received new attention. Following successful breeding results in recent years, the use of tall fescue has also increased. Tall fescue is a good example of a species for which breeders have recently improved the quality and palatability in combination with existing good performance (Halling & Larsson, 2017). Good tolerance to both wet and dry conditions is a desirable characteristic in a changing climate.

Table 5. Certified + imported seed of the main silage crops in Sweden (10^3 kg year^{-1}). Percentage forage legumes/forage legumes and grasses (Swedish Board of Agriculture, 2018b)

Species		2002/2003		2009/2010		2017/2018	
English name	Latin name	10^3 kg	%	10^3 kg	%	10^3 kg	%
Red clover	*Trifolium pratense* (L.)	806.7	78	550.4	64	473.8	42
White clover	*Trifolium repens* (L.)	155.8	15	139.9	16	430.5	38
Alsike clover	*Trifolium hybridum* (L.)	13.8	1	31.5	4	40.5	4
Lucerne	*Medicago sativa* (L.)	60.0	6	127.5	15	187.3	16
Birdsfoot trefoil	*Lotus corniculatus* (L.)	4.2	0	6.7	1	9.1	1
Total forage legumes		*1 040.5*	*100*	*856*	*100*	*1 141.2*	*100*
Timothy	*Phleum pratense* (L.)	2 072.9	39	1 859.9	46	2 177.3	44
Meadow fescue	*Festuca pratensis* (Huds.)	1 567.9	29	722.9	18	1 502.3	30
Tall fescue	*Festuca arundinacea* (Schreber)	29.0	1	253.1	6	312.4	6
Perennial ryegrass*	*Lolium perenne* (L.)	1 513.5	28	1 022.3	25	777.4	16
Hybrid ryegrass	*Lolium x boucheanum* (Kunth)	40.5	1	-	-	29.0	1
Festulolium *ssp.*	*x Festulolium*	49.0	1	96.1	2	-	-
Cocksfoot	*Dactylis glomerata* (L.)	69.8	1	68.6	2	196.0	4
Total forage grasses		*5 342.6*	*100*	*4 022.9*	*100*	*4 994.6*	*100*
Legumes/(legumes + grasses)			16.3		17.5		18.6

* includes amenity varieties

To conclude, the main breeding targets for forage crops in Sweden are large yield, persistence (i.e. winter hardiness and pest resistance), high nutritive value (e.g. concerning digestibility, crude protein and fibre quality) and satisfactory seed production.

More intensive harvesting regimes

Traditionally, cutting frequency was restricted to two cuts a year in Sweden, due to the short growing season. Several investigations have shown that production is greater, but quality is lower, with two cuts compared with three cuts a year in mixed swards with timothy, meadow fescue, and in some treatments red clover, a commonly used seed mixture (Table 6).

Table 6. Dry matter yield (kg DM ha^{-1}) and digestible energy (MJ kg^{-1} DM) in grass and mixed swards with two and three cuts a year, with 100 kg N ha^{-1} supplied in both cases (Kornher, 1982)

	2 cuts		3 cuts	
Seed mixture	Yield	Energy	Yield	Energy
Timothy + meadow fescue	7 760	10.0	6 210	10.9
Timothy + meadow fescue + red clover	9 110	10.0	8 035	10.3

White clover also for silage

To improve forage-based diets in terms of required nutritional quality and quantity, the choice of species and of suitable management strategies is crucial. High digestibility, ensuring large forage intake and slow decline with time are major advantages in legumes compared with grasses, especially when the weather is unpredictable. Traditionally, white clover was grown for grazing in Sweden. However, in the 1980s, more erect varieties of white clover were introduced and studies were carried out to test the potential for inclusion of white clover in mixed, short-term leys.

An extensive study (15 field trials) was carried out with two different mixtures of white or red clover with timothy and meadow fescue, and smooth-stalked meadow grass (*Poa pratensis* L.). Three nitrogen levels were included (0, 100 and 200 kg N ha^{-1}). The swards were cut three (silage or hay developmental stages) or four times a year for four consecutive years (Svanäng & Frankow-Lindberg, 1994). On average for different fertilising and cutting regimes, the white clover/grass mixtures (WC) were found to be better than the red clover/grass (RC). The yield from WC with no fertiliser N supplied was about the same in the fourth year as in the first year (7700 kg DM ha^{-1}) (Table 7). The corresponding yield in RC decreased from 8400 to 5500 kg DM ha^{-1}, resulting in an increasing amount of weeds. Irrespective of harvesting regime, root rot is the major obstacle to more long-lived RC swards. An early first cut and short defoliation intervals increased the WC content. Nitrogen fertilisation increased the DM yield, but decreased the clover percentage and the clover yield in the sward. Due to less competitiveness, WC content was more depressed than RC content when N was applied. The marginal effect of N on DM yield was largest in the 0-100 kg N ha^{-1} interval (Table 8). It was larger in RC than in WC except in the first year with 100 kg N ha^{-1}. The introduction of white clover facilitated more flexible sward management, sometimes with harvesting and grazing in combination.

Table 7. Effect of nitrogen application on dry matter yield (kg DM ha^{-1}) in mixed swards fertilised with 0, 100 and 200 kg N ha^{-1}. Mean for *Trifolium* ssp. and harvesting systems (Svanäng & Frankow-Lindberg, 1994)

N level	*Trifolium* ssp.	1st year	2nd year	3rd year	4th year
0 kg N	Red clover	8 430	7 647	6 363	5 491
	White clover	7 724	8 085	7 441	7 765
100 kg N	Red clover	9 597	9 359	7 795	7 141
	White clover	9 123	9 534	8 169	8 152
200 kg N	Red clover	10 409	10 202	8 569	8 213
	White clover	9 920	10 246	8 619	8 565

Table 8. Dry matter yield (kg DM kg^{-1} N) in mixed swards on the margin of nitrogen application in the intervals 0-100 kg N ha^{-1} and 100-200 kg N ha^{-1}. Mean for *Trifolium* ssp. and harvesting systems (Svanäng & Frankow-Lindberg, 1994)

N level	*Trifolium* ssp.	1st year	2nd year	3rd year	4th year
0–100 kg N	Red clover	11.8	17.4	14.5	13.0
	White clover	14.4	14.7	7.7	7.2
100–200 kg N	Red clover	8.3	8.7	8.2	10.1
	White clover	8.2	7.3	4.8	3.9

Most of the available forage seed mixtures contain both red and white clover. Frankow-Lindberg *et al*. (2009) found that red clover as a single legume species or in a mixture was superior at a dry site, while multi-clover/grass species mixtures were superior at a wet site. Stability of clover yields can generally be increased by including both white and red clover in the seed mixture, but not total DM yield.

White clover for less intensive silage systems?

White clover is more persistent than red clover and higher yielding in intensively cut systems. The studies in the late 1980s led to growing interest among Swedish farmers in using white clover as a silage crop. The question was whether white clover could be recommended in areas with less intense production systems due to farming tradition and climate conditions.

In a study with 11 field experiments in southern and central Sweden, mixed swards containing red or white clover were cut two or three times a year for three years following establishment, and fertilised with 0 or 100 kg N ha^{-1} (Nilsdotter-Linde *et al*., 2002). The number of cuts significantly affected DM yield, but the response varied between sites and with sward age (Figure 3). The effect of N on DM yield was positive, on average, in both red and white clover/grass mixtures. Nitrogen fertilisation rate significantly (P < 0.001) affected DM yield of individual cuts and total yield per year (Figure 3). The number of cuts also affected yield, with two cuts giving larger total yields than three, an effect that increased with sward age. On average, the difference between red and white clover yield was small, but in the third year unfertilised white clover yielded more than unfertilised red clover.

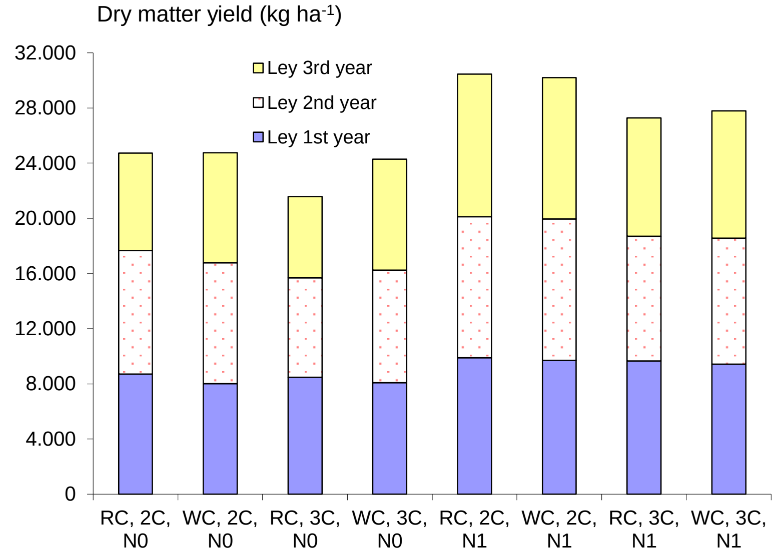


Figure 3. Total dry matter yield (DM, kg ha^{-1}) for combined treatments (all cuts and years) as an average of 11 field experiments. RC = red clover, WC = white clover, 2C = two cuts year^{-1}, 3C = three cuts year^{-1}, N0 = 0 kg N ha^{-1}, N1 = 100 kg N ha^{-1} (Nilsdotter-Linde *et al*., 2002).

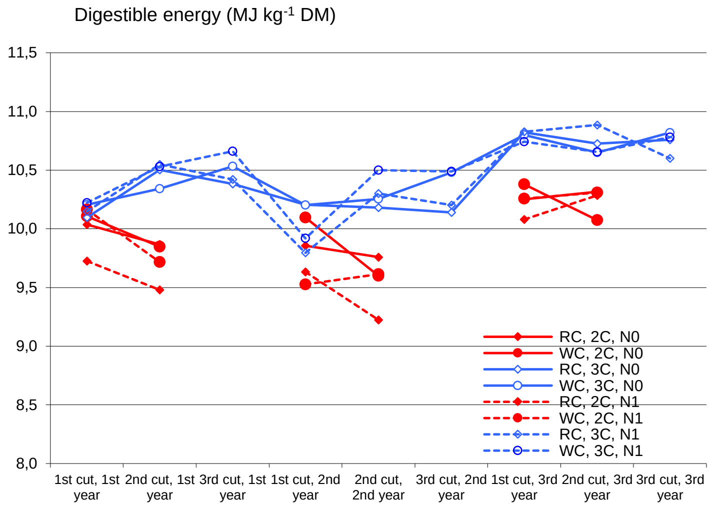


Figure 4. Digestible energy (MJ kg^{-1} DM) calculated from rumen-soluble organic matter as an average of nine field experiments in all treatments at each cut in years I–III. RC = red clover, WC = white clover, 2C = two cuts year^{-1}, 3C = three cuts year^{-1}, N0 = 0 kg N ha^{-1}, N1 = 100 kg N ha^{-1} (Nilsdotter-Linde *et al*., 2002).

The number of cuts had the largest effect on the mean nutritional quality of the herbage, especially digestible energy (MJ kg^{-1} DM) (Figure 4), although at quite low levels in many cases (<10.5 MJ kg^{-1} DM). Neutral detergent fibre was higher in N-fertilised treatments than with no fertiliser N, while crude protein was higher in treatments with three cuts and where the legume content was high. That was the case in plots with no fertiliser N supplied and where the white clover fraction increased, as occurred during the third year. In some cases, the content of crude protein was above 200 g kg^{-1} DM.

The conclusion was that total yields of white clover and red clover in mixed swards were similar in young swards and with two cuts per year. However, unfertilised white clover yielded more in the third year. The nutritional quality, especially digestible energy, was much better with three cuts than with two.

Lucerne for dry conditions
In the early 1980s, there was much field research on lucerne in Sweden, which was soon implemented by farmers in appropriate regions with a high soil pH. Soil inoculation with a suitable *Rhizobium* strain improves lucerne yield substantially (Jönsson, 1982). Following successful introduction, there were some setbacks owing to hard winter damage followed by very sparse swards. The winter buds just below the soil surface need oxygen and are susceptible to standing water and ice coverage. Field topography and drainage status are very important when including lucerne in leys. In recent years, there has been renewed interest in this crop for reasons such as the high fibre quality, the need for more home-grown protein in the ration and perhaps more pronounced dry periods in the summer.

Ryegrasses – possibilities and threats
With the arrival of intensive harvesting systems with more white clover included for silage, ryegrasses have become more interesting, even at Swedish latitudes. Large yield in combination with high quality is their major advantage. However, the reason why these species are not as prevalent in Scandinavia as further south is that their longevity is more or less restricted depending on climate conditions, with winter kill always a threat. Perennial ryegrass is only recommended in the southern third of Sweden.

Swedish farmers have very good knowledge about management of domestic timothy, but are less knowledgeable about different treatments for improving the overwintering capacity of ryegrasses. In nine field experiments with perennial ryegrass in the official testing programme in eastern and western Sweden in the early 1990s, late autumn cutting was tested as a tool to reduce damage caused by e.g. snow mould (*Fusarium nivale*) and thus improve winter survival (Halling, 1994). Because of extremely mild winters with low occurrence of snow mould fungi in the study period, cutting as late as possible before cessation of growth significantly reduced the following spring yield by about 25% in both the second and third year (Table 9). There was no residual effect of late autumn cutting on subsequent cuts.

Table 9. Effect of autumn cutting management on subsequent dry matter (DM) yields in perennial ryegrass
(10^3 kg DM ha^{-1}, mean different varieties) (Halling, 1994)

	DM yield				
	2nd year				3rd year
Treatment	1st cut	2nd cut	3rd cut	Total yield	1st cut
With late autumn cut	3.31	1.94	2.56	7.81	2.40
Without late autumn cut	4.46	1.92	2.71	9.11	3.25
Significance	**	NS	NS	*	**

Significance: NS = *P* > 0.05, **P* < 0.05, ***P* < 0.01, ****P* < 0.001.

The growing interest in different ryegrasses and their hybrids is encouraging breeders and researchers to focus on better varieties and management strategies, and there are ongoing investigations on how cutting strategy influences overwintering capacity.

Forage species adapted for different purposes

There is increasing interest in species with special qualities, e.g. water-soluble carbohydrates and condensed tannins. Studies on birdsfoot trefoil, a minor forage legume containing condensed tannins, have confirmed that it can withstand Swedish climate conditions. This has led to an extensive trans-disciplinary investigation of its population ecology, protein efficiency and anti-parasitic effects in ruminants (Nilsdotter-Linde *et al*., 2002), followed by a performance investigation in heifers (Nilsdotter-Linde *et al*., 2004) and a corresponding investigation in dairy cows. A tendency for larger milk yield and somewhat higher milk protein concentration resulted in higher protein yield with a birdsfoot trefoil diet compared with a white clover diet (Eriksson *et al.*, 2012). The most appropriate variety for Swedish conditions is cv. Oberhaunstaedter, which has shown good persistence and relatively high content of condensed tannins (1-2 g kg^{-1} DM) in the official variety testing programme (Halling & Larsson, 2017).

Conclusions and future tasks

In Sweden, ruminants and horses rely on preserved forage, as the grazing season is about four months in the south and only two months in the north. In the 1960s, hay making dominated completely, but over the following 20 years there was a dramatic change to silage making. Less dependency on good harvesting weather, better technical solutions and better animal response were the most important factors for this change. The large dairy herds were the first to change to grass and legume silage, stored in tower or bunker silos. When round bales arrived in the 1990s, smallholders too began making silage, while horse owners converted when small bales and haylage were introduced.

When silage replaced hay, the cropping system changed to more intensively managed, short-term leys. Two cuts were replaced by three in central and northern Sweden and four or more in southern Sweden. Sward composition also changed, with white clover included for silage and with ryegrasses becoming more popular. However, ryegrass still has problems with winter kill and remains a minority grass in Swedish leys. It is a challenge to find the right plant material combining persistence, large yield and high quality. Farmers have to formulate their own strategy regarding longevity, fertilisation, harvesting intensity and the purpose of production in choosing the right seed mixture.

There is currently renewed interest in producing home-grown protein to replace imported protein. Temporary grasslands provide a large proportion of the protein needed, but more can be done to produce large yields of the proper quality for different animal categories. More emphasis has to be put on plant breeding and improved management to achieve more persistent swards for grazing and harvesting. According to recent research and experiences from other countries, improved grazing management can make a major difference to the economics of grazing. Deeper knowledge about cultivation of grasses and legumes that are more tolerant to dry and/or wet conditions is important, to better face upcoming climate changes.

Within the research area of silage production from grasslands, DM losses during silage making are gaining interest. The magnitude of the DM losses differs significantly between the silo systems in use. Our research showed that the losses in tower silos and bunker silos were about 15%, while those in round bale silos were in the region of 1%. These figures indicate that, with maintained production level, the total acreage cultivated as forage could be decreased by about 10% through appropriate management of silos and silage making processes.

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7.2 Ireland

Fergus Bogue, Michael O'Donovan (Teagasc)

Grazed grass is the cheapest and most widespread feed for ruminant production systems in Ireland. Grass enables low-cost animal production and promotes a sustainable, green, and high quality image of milk production across the world. Recent industry reports (FoodHarvest 2020 and FoodWise 2025) have highlighted the important role grass can play in an expanding milk production industry. Through a combination of climate and soil type, Ireland possesses the ability to grow large quantities of high quality grass and convert it through the grazing animals into high quality grass based milk and meat products.

Our competitive advantage in milk production can be explained by the relative cost of grass, silage and concentrate feeds. Therefore, increased focus on grass production and efficient utilisation of that grass should be the main driver for expansion of the livestock sector. An analysis of farms completing both grassland measurement in PastureBase Ireland and a Profit Monitor demonstrated increased profit of €181/ha for every 1 tonne DM/ha increase in grass utilised. It should be noted that issues such as environmental sustainability (carbon footprint, nutrient use efficiency, etc.) are also improved by increased grass utilisation.

Future growth in the pasture based milk production in Ireland will depend on an effective grass-based system. However, Irish farmers are not using grass to best effect and there is thus a need to (1) increase grass production and (2) ensure efficient utilisation of that grass.

Current Grazing Performance on Dairy Farms

Currently, it is estimated that about 8 tonnes grass DM/ha is utilised nationally on dairy farms (Dillon, 2016). There are major improvements required in areas of pasture production and utilisation. Data from the best commercial grassland farms and research farms indicate that the current level of grass utilised can be increased significantly on dairy farms (greater than 10 t DM/ha utilised – i.e. 14 tons DM/ha grown and 75% utilisation rate).

It is important to recognise that improvements in the level of soil fertility, grazing infrastructure and level of reseeding are in achieving higher levels of grass production and utilisation. However to achieve greater change in the level of grass utilised, farmers will need to upskill their grazing management practices. This means regular measurement of grass cover, using specialised grassland focused software to analyse grass production and, making and implementing grazing management decisions. These are key drivers to increasing grass production on the farm. New technologies are now available which make grass cover assessment and the decision making process much easier.

Soil Fertility Management

Good productive soils are the foundation of any successful farming system and key for growing sufficient high quality grass to feed the herd. Therefore, the management of soil fertility levels should be a primary objective of every farm. A recent review of soils tested at Teagasc indicates that the majority of soils in Ireland are below the target levels for pH (i.e. 6.3) or P and K (i.e. Index 3) and will be very responsive to application of lime, P and K. On many farms sub-optimal soil fertility will lead to a drop in output and income if allowed to continue. Teagasc is highlighting 5 steps for effective soil fertility management.

1. Have soil analysis results for the whole farm (soil sampling every 2 years)

2. Apply lime as required to increase soil pH up to target pH for the crop

3. Aim to have soil test P and K in the target Index 3 in all fields

4. Use organic fertilisers as efficiently as possible

5. Make sure the fertilisers used are properly balanced

For those farmers aiming to improve soil fertility on their farms, following these 5 steps provides a solid basis for success.

Phosphorus (P)

The proportion of soils tested with low soil P fertility (i.e. P Index 1 and 2) has increased to approximately 62%. This overall trend reflects the soil P fertility status on many farms, and indicates a serious loss in potential productivity. Recent research has shown that soils with P index 3 will grow approximately 1.5 t dry matter (DM)/ha per year more grass than soils with P Index 1. Most of the DM yield response in these experiments took place in spring and early summer.

Potassium (K)

Soil analysis shows that the trend in soil K status, across dairy and drystock enterprises, broadly mirrors that for P. Despite no legislative limits on K fertilisers, K usage dropped in line with P fertiliser applications. Consequently soil test results indicate a sharp increase in soils with low K status between. Over half of the soil samples tested by Teagasc had very low to low soil K status (i.e. K Index 1 or 2).

Increasing Soil Nutrient Availability-Lime

Lime is a soil conditioner and corrects soils acidity by neutralising the acids present and allowing the micro-organisms and earthworms to thrive and break down plant residues, animal manures and organic matter. This helps to release stored soil nutrients such as nitrogen (N), phosphorus (P), potassium (K), sulphur (S) and micro-nutrients for plant uptake. In addition, ryegrass and clover swards will persist for longer after reseeding where soil pH has been maintained close to the target levels through regular lime applications.

Liming acidic soils to correct soil pH will result in the following:

- Increased grass and crop production annually

- Increase the release of soil N by up to 60 units N/acre/year
- Increase the availability of soil P and K and micronutrients
- Increase the response to freshly applied N, P and K as either manures or fertiliser

Ground limestone is the most cost effective source of lime and can be applied throughout the year when the opportunity arises. Lime is the foundation of soil fertility and is a primary step to take when correcting soil fertility.

Investing in Grazing:

In order for expansion to be successful, there will be a requirement for significant investment on many farms. The available capital for this investment will be scarce as expansion happens and continues. Therefore, investment on farm should be prioritised at areas that increase efficiency and reduce the exposure of the business to external shocks such as lower price of product or higher price of inputs etc. All investments that give the highest returns should be prioritised.

Every ton of additional grass eaten by the grazing animal will add €180/ha additional profit to a dairy farm. Therefore it is important that investment in grazing is prioritised to give the maximum return. The table below summarises the potential return on investment for different investments in a dairy farm business. Bottom Line: the level of return to these investments is high because it is investing in grazing. These investments will either enable the farm to grow more grass or lengthen the grazing season or both.

Investment	Cost	Impact	Annual Return (%)
Increase soil P & K levels	P & K application of 20 and 50kg/ha	+1.5 t DM/ha/year grass growth	152
Reseed full farm in eight year cycle	€650/ha	+ 1.5t DM/ha/year grass growth	96
Improve grazing infrastructure	€1,000/ha for roads, fencing and water	+ 1.0 t DM/ha/year grass eaten/utilised	58

The need for more reseeding

As grass is our main feed during the main grazing season, and the primary source of winter forage in the form of grass silage, the low level of reseeding must be addressed. Reseeding must be combined with managing, and where necessary increasing, soil fertility. Ireland will continue to increase milk production and the focus on efficient production of this milk is critical to maintain our industry competitiveness. Teagasc have developed a national grassland database (PastureBase Ireland), and the initial results show that there is huge capacity on Irish farms to grow more grass. The objective here is to outline the key points in grassland reseeding and to ensure farmers making the investment in renovating grassland get the best possible result.

Why reseed?

Productive grassland farms must have perennial ryegrass dominated swards. Recent Moorepark research shows that old permanent pasture produces, on average, 3 t DM/ha per year less than perennial ryegrass dominated swards. Old permanent pasture is up to 25% less responsive to available nutrients such as nitrogen than a perennial ryegrass dominated sward. Reseeding is a highly cost effective investment. With regular reseeding the grass growth capacity of the farm can be increased substantially and the annual return of investment is large.

Objectives of reseeding are to create swards that:

(1) Increase the overall productivity of the farm
(2) Increase grass quality
(3) Are responsive to fertiliser - at least 10 kg DM/kg N applied
(4) Allow higher animal output - 8% higher milk output per hectare relative to permanent pasture
(5) Increase grass utilisation
(6) Reduce silage requirement
(7) Increase the productivity of the farm (carry a higher stocking rate)
(8) Can allow clover to establish

Reseeding Checklist

- Identify paddocks for reseeding (poorer performing paddocks; low perennial ryegrass content)
- Soil test and lime
- Sowing date
- Method of reseeding
- Spray off paddock
- When cultivating - prepare a good seed bed
- Choose appropriate grass cultivars
- Sowing rate
- Roll
- Slug and other pests

- Control weeds early
- Graze at 2 leaf stage
- Avoid poaching and over grazing

Cultivation techniques

How paddocks are prepared for reseeding depends on soil type, amount of underlying stone and machine/contractor availability. There are many different cultivation and sowing methods available. All methods, when completed correctly, are equally effective.

Key points

- Spray off old sward
- Graze sward tightly or mow to minimise surface trash
- Apply lime
- Choose a method that suits your farm
- Soil test
- Firm fine seedbed with good seed/soil contact is essential
- Roll after sowing

	Do's	**Do not's**
Ploughing	Shallow plough. Develop a fine, firm and level seedbed	Plough too deep (>15 cm). Cloddy, loose seedbed
Discing	Graze tight, apply lime. 3-4 runs in angled directions	Forward speed too fast - rough, uneven seedbed
One-pass	Graze tight, apply lime. Slow forward speed at cultivation	Forward speed too fast – rough, patchy seedbed
Direct drill	Graze tight, apply lime and slug pellets. Wait for moist ground conditions (slight cut in ground)	'Trashy' seedbed - no seed/soil contact. Use when ground is dry and hard

Variety choice

The DAFM publish the Recommended List, showing the Pasture Profit Index values and agronomic values of the evaluation on the same table (see https://www.teagasc.ie/crops/grassland/pasture-profit-index/).

The Recommended List has evaluated varieties across years and sites and is the only evidence available of the potential performance of grass cultivars in Ireland. Using varieties not on this list is basically poor decision making, as is buying grass seed on price. The varieties you use on the farm, will be there for 8-12 years, choosing to use cheap mixes, with non-recommended varieties will increase the chances of those varieties failing to perform on the farm.

Pasture Profit Index (PPI)

Variety	Sub-indices (€ per ha per year) Seasonal Yield	Quality	Persistency	Silage	Total Merit
AberClyde	142	55	0	28	225
AberMagic	170	30	0	17	217
Fintona	152	24	0	39	215
AberZeus	169	9	0	34	212
Nifty	194	-12	0	26	208
Moira	198	-18	0	27	207
AberGreen	186	16	0	4	206
AberPlentiful	154	29	0	20	203
AberGain	119	60	-11	30	198
AberChoice	122	59	0	13	194
Meiduno	146	27	0	21	194
Dunluce	125	37	0	30	192
Elysium	138	31	0	20	189
AberWolf	142	25	0	21	188
Seagoe	129	14	0	42	185
Astonconqueror	149	7	0	24	180
AberBite	102	51	-11	33	175

Variety	Sub-indices (€ per ha per year) Seasonal Yield	Quality	Persistency	Silage	Total Merit
Rosetta	158	-4	0	20	174
Solas	122	26	0	19	167
Kintyre	116	27	-5	18	156
Astonenergy	86	59	0	8	153
Xenon	91	40	0	19	150
Carraig	121	-16	0	35	140
Solomon	140	-28	0	25	137
Alfonso	82	45	0	7	134
Aspect	84	33	0	14	131
Navan	96	12	0	16	124
Drumbo	93	39	-11	0	121
AberLee	76	42	0	3	121
Kerry	113	-5	0	11	119
Glenroyal	104	-3	0	11	112
Clanrye	90	-15	0	20	97
Majestic	109	-26	0	5	88
Glenveagh	70	-21	0	12	61

When the decision to reseed is made, the next major decision is selecting the most appropriate grass variety or varieties. The first thing to consider is the primary target use of the field. Is it predominantly grazing or is it generally used as a silage paddock? How much tetraploid should be used? A balance between quality, dry matter productivity and sward density is generally what must be achieved.

The key traits in a seasonal grass based production system are:

- High quality
- High seasonal production
- Good persistency score

Differences between diploid and tetraploid varieties:

Tetraploid varieties	Diploid varieties
Tall upright growth habit	Prostrate growth habit
Create more 'open' sward	Create a denser sward with less "open" spaces
Higher digestibility value	Generally lower digestibility and yield

Combining diploids and tetraploids in a mixture will create a dense, high quality sward – ensure you select varieties which express high performance in the key traits. Increasing the proportion of diploids on heavier soils is recommended to create better ground cover, however tetraploids should be used on heavy soils. Choosing all dense varieties will compromise DM production and grazing utilisation.

Management of new reseeds:

	Do's	Do not's
First 8 weeks	Graze at 2-3 leaf stage Spray weeds before grazing Nitrogen and P & K Slug pellets (if required)	Graze at high cover (>1400 kg DM/ha) Do not harvest for silage
Second grazing onwards	Graze at 1,200 - 1,600 kg DM/ha (6-8 cm) Re-spray weeds if necessary	Allow high covers to develop Graze in really dry or wet conditions
Autumn	Keep grazing at 1,200 - 1,600 kg DM/ha Graze off well before first winter (>4 cm) Light slurry application	Overgraze or poach Apply excessive slurry
Second year	Ensure the new sward receives adequate nitrogen Monitor soil P and K status	Overgraze or poach

Graze the new reseed as soon as the plants do not pull out of the ground. Plants will normally be 6 – 8 cm high. It is especially important that autumn reseeds are grazed before the first winter.

The first grazing does not have to be completed by the main grazing herd, calves or young stock may be a better option, particularly during poor grazing conditions.

All the benefits of reseeding can be lost after sowing due to:

- Poor soil fertility - poor establishment and tillering
- Grazing at high grass covers or cutting for silage – tiller/plant death
- Weed infestation (especially docks) – loss of ground cover
- Pest attack (frit fly, leatherjackets and slugs) – tiller/plant death

Tillering

Tillering is the production of new grass plants by the main grass plant established from the seed. The process of grass tillering is critical for successful sward establishment. Tillering helps reduce the space available for weeds. To encourage tillering:

- Apply 40 kg N/ha 3-4 weeks after sowing
- Graze the reseed when it is about 6-8 cm high

- Continue to graze the reseed in the first year of production
- Avoid cutting the new reseed for silage in the first year (if possible)

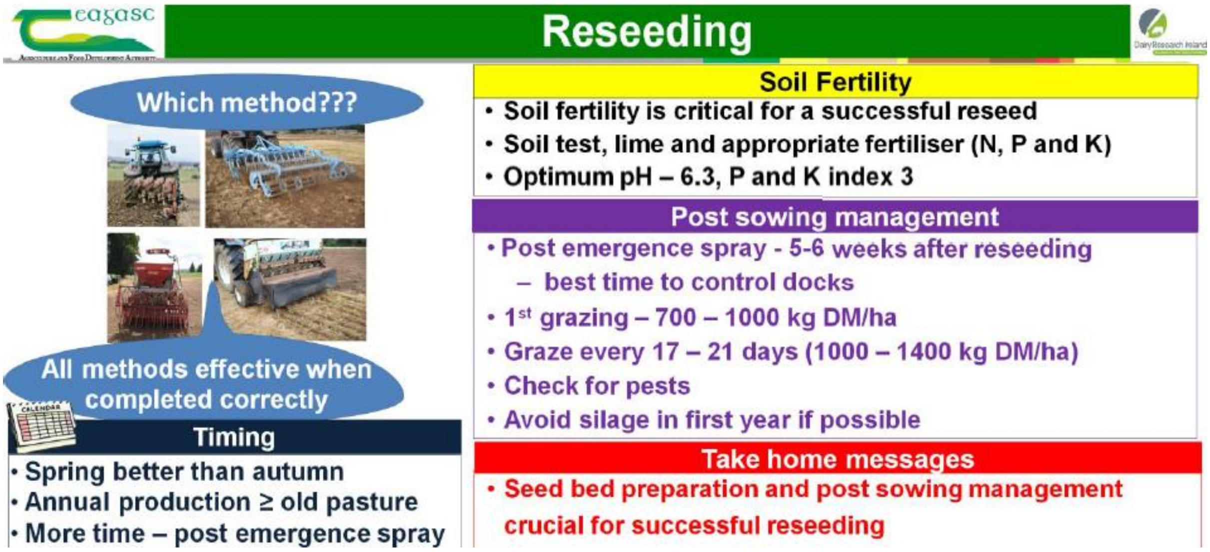
Weed Control:

- Weeds in new reseeds are best controlled when the grass is at the 2-3 leaf stage
- Docks and chickweed are the two most critical weeds to control in reseeds
- High populations of other weeds such as fat hen, charlock, redshank, mayweed can cause problems
- It is essential to control docks and chickweed at the seedling stage and this is achieved by applying a herbicide before the first grazing
- To achieve the best lifetime control of docks in a sward, eradicating the dock at seedling stage in a reseed is the best opportunity
- Herbicide choice for dock control will depend on the presence of clover in the reseed (see Herbicide Guide)
- Chickweed can be a problem particularly where regular grazing is not expected to take place (silage fields), therefore herbicide choice is important
- You should consult your local adviser or merchant representative for correct herbicide choice
- Remember to keep the prescribed cross-compliance records and follow the instructions on the product label

Reseeding Investment

Reseeding is one of the most cost effective investments that can be made on a grassland farm. Projected costs:

	€/acre
Spraying	10
Glyphosate (Gallup 360) (Round-up (2 litre/acre)	16
Ploughing (€30)/ Till & sowing (one pass) (€30)	60
Fertiliser (2 bags × 10:10:20)	37
Fertiliser spreading	10
Levelling	10
Rolling	10
Grass seed	60
Post emergence herdicide sprays	30
Spraying	10
Costs (ex- post emergence sprays)	**253**



PastureBase Ireland

Technologies which enable data-informed decision-making on the farm can help to increase farmers' confidence and greatly improve grassland management. Huge leaps have been made in developing decision support tools to improve resource farm efficiency, profitability and sustainability. The primary objective of most of these tools is to increase the information available to assist in farm-management decision making as well as to collect and collate large amounts of data in a centralised database. Teagasc launched PastureBase Ireland (PBI) – an online grassland management decision support tool – in January 2013 and Grass10 will see the roll-out of the new PastureBase Ireland website as a key component of the campaign. Upon entering data from their own farm (e.g. grass measurements), the platform provides real-time and customised grassland management advice to the farmer to assist their decision-making. These reports are developed in such a way that allows farmers to benchmark their individual farm with farm in their discussion group or in their region. The data accumulated to date indicate that PBI participating farms have achieved improvements in grass DM production and grazing management.

PastureBase Ireland is informing us that farmers need to have a good control of current grass supply in order to manage grass well. Grass cannot be managed correctly without knowledge of farm cover, grass demand and grass growth. The crucial point on any farm is utilising the feed resource produced on the farm.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Agriculture and Food Development Authority
PastureBase Ireland (PBI)
PastureBase IRELAND
What is PBI?
• Grassland management service
• Merged with AgriNet Grass
• Use it on your smart phone – www.pbi.ie
Pasture Base Ireland Open
What can PBI do for you?
• Increase profitability of your farm
• Better grazing management
• Confidence to remove surplus
• Ranks paddocks on performance
• Compare results with your discussion group members
Sign up Today!
Tools include;
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4. Fertiliser records
More
= More

7.3 The Netherlands

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The description for the Netherlands is partly based on *Van Dijk et al. (2015) and van den Pol-van Dasselaar et al. (2015 and 2018).*

Description of the country

The Netherlands is a small and densely populated country. There are about 16.8 million inhabitants on about 4.15 million ha. This corresponds to 406 inhabitants km^{-2}. The area of cultivated land amounted to 2.3 million ha in 1960, but in somewhat more than 50 years this area decreased by about 500,000 ha due to conversion into urban areas, industrial areas and nature areas.

Agriculture is of great economic importance for the Netherlands. The country is more than self-sufficient in many agricultural products. The total value of exports of all agricultural products amounted to about 75 billion Euro annually during recent years. Cattle husbandry contributed significantly to that export, e.g. via dairy products, cattle and beef.

The baseline for dairy production is good. The infrastructure is good (harbours, airports, roads), and therefore materials that are needed can easily be accessed. The Dutch agrosector is important for the Dutch economy; it ranks together with France in second place on the list of exporters of agricultural products, behind the United States. The Netherlands is a world-leading exporter of milk and milk products. Furthermore, there is a good knowledge infrastructure in the Netherlands (universities, schools, advisory, farmers associations) that enables farmers to quickly assess up-to-date information to optimise their farm management.

Dairy farming systems in the Netherlands: developments and characteristics

At present dairy farms in the Netherlands are usually specialised, i.e. their main activity is dairy production. In the Netherlands, forage production and grassland management have undergone substantial changes over the last 50 years. Yields, quality and utilisation of crops increased due to improved grassland management, fertilisation and breeding. The average number of dairy cows per farm increased tenfold to about 85, average milk production per cow doubled to somewhat more than 8,000 kg milk cow^{-1}, average milk production per ha tripled to about 15,000 kg ha^{-1} and the number of dairy farms declined tenfold to about 18,000. This is illustrated in Table 1, where a number of key parameters for the period 1960 - 2015 are shown.

Table 1. Developments in dairy cattle husbandry in the Netherlands (Van Dijk *et al.*, 2015).

	1960	1975	1985	1995	2005	2010	2013
Agricultural area (x1000 ha)	2317	2082	2019	1965	1938	1872	1848
Grassland area (x1000 ha)	1327	1286	1083	1048	976	951	932
Forage maize area (x1000 ha)	0.5	77	177	219	235	229	230
Number of dairy farms (x1000)	183	91.5	58	37.5	23.5	19.3	18.5
Number of dairy cows (x1000)	1628	2218	2367	1708	1433	1479	1553
Number of cows farm^{-1}	8	24	41	46	61	75	84
Kg milk cow^{-1} yr^{-1}	4205	4650	5330	6610	7550	8000	7990
Kg concentrate cow^{-1} yr^{-1}	800	1590	2280	2210	2020	2060	
Kg milk ha^{-1} yr^{-1} (x1000)	5.5	8.86	12.51	12.02	12.56	14.07	
Kg milk farm^{-1} yr^{-1} (x1000)	37	112.5	217	302	460	597	671
Kg milk in Holland yr^{-1} (mill. tons)	6.7	10.3	12.5	11.3	10.8	11.9	12.2
Kg milk hr^{-1} labour	8	37	72	89	128	150	
Dairy cows ha^{-1} grass and forage crops	1.2	1.6	1.8	1.3	1.2	1.2	1.3

The developments in milk production per cow and numbers of dairy cattle is shown in Figure 1 at the national level for the Netherlands. Until spring 2015, the EU milk quota system limited the maximum amount of milk produced per country. The total number of dairy cows decreased following the introduction of the milk quota system in 1984 and the average milk production per cow increased.

The method of milking changed significantly, going from milking by hand to milking robots. Currently, around 25% of the Dutch dairy farmers is milking with a milking robot (KOM, 2019). Amongst others, this led to a large increase in the number of dairy cows that can be managed by one person.

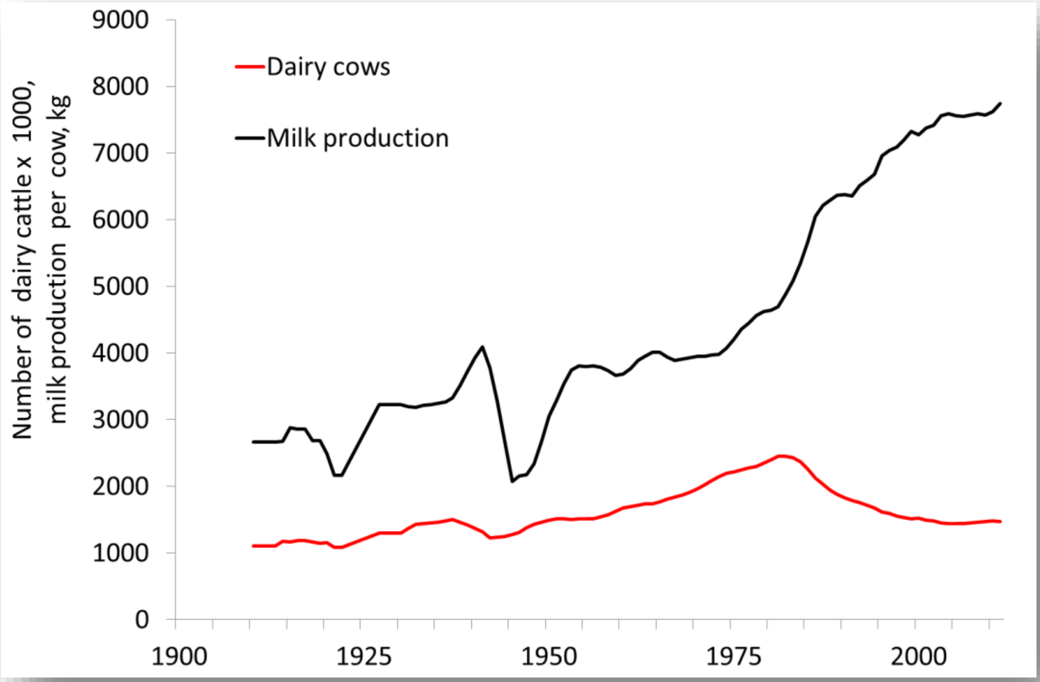

Figure 1. Changes in number of dairy cows and in milk production per dairy cow in the Netherlands from 1910 to 2011 (data CBS; Van den Pol-van Dasselaar *et al*., 2015).

<u>Soils</u>

Even in relatively small land areas, such as the Netherlands, large regional differences in soil quality exist. Soil formation is strongly influenced by the North Sea and the rivers Rhine and Meuse that flow through these regions, and also by climate and human intervention. Approximately 60% of the Netherlands is situated below sea level (-1 to -7 meter) and protected by dykes, dams and dunes. Clay soils are mainly found near the sea, near the rivers and in the areas that were reclaimed from the sea. Peaty soils are found in the western and northern parts of the Netherlands. Sandy soils are mainly situated in higher parts of the Netherlands which are above sea level in the east and the south of the country.

The regional differences in soil type are reflected in regional differences in soil quality. Part of this fertility was inherited from the sea and the river deltas, part is man-made (by e.g manure applications). The soils in the eastern and southern part of the Netherlands were originally mostly poor sandy soils. Current fertility status of soil organic matter content and soil P content in the Netherlands is shown in Figure 2. The peaty (marine) soils in the West and the North of the Netherlands can be recognised as areas with a relatively high soil organic matter content. Soil P content is generally high.

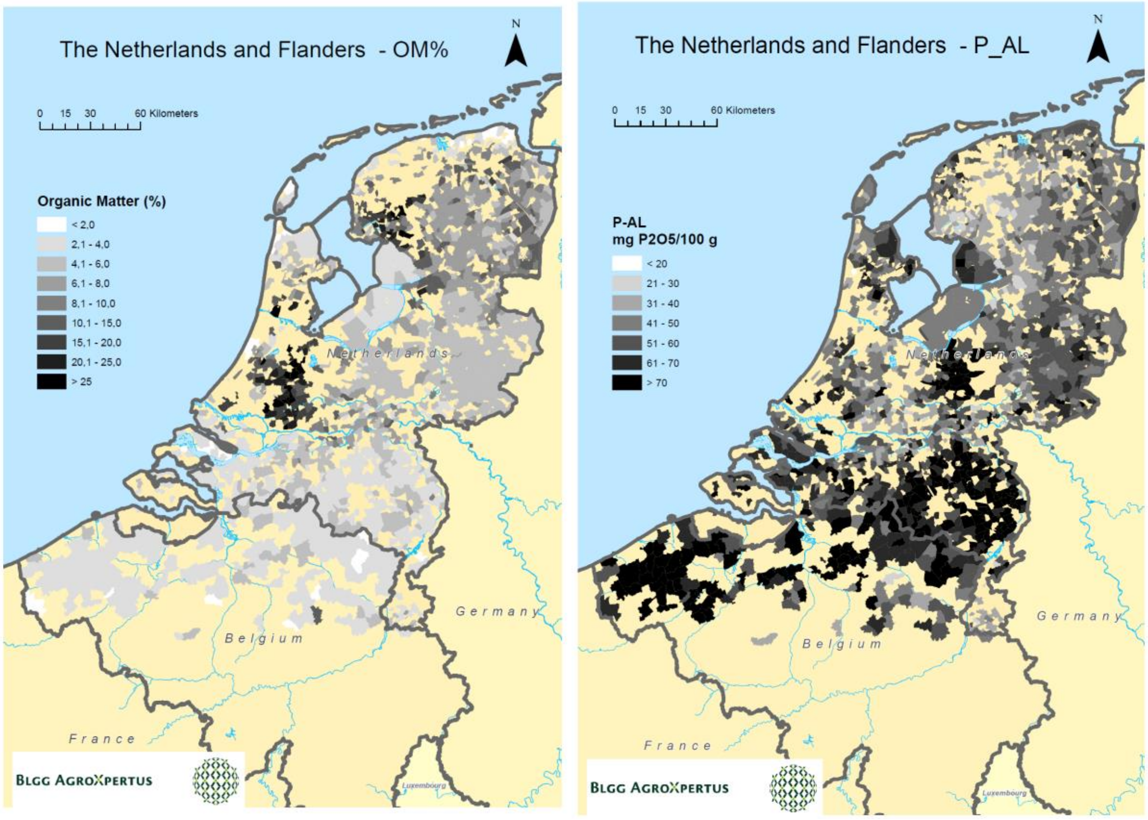

Figure 2. Examples of soil quality in the Netherlands: a) soil organic matter content (%), and b) P content, P-Al, mg P_2O_5 / 100 g. Source: Blgg AgroXpertus, average of >70,000 samples in the Netherlands (Van den Pol-van Dasselaar *et al*., 2015).

<u>Grassland</u>

Grass is the most important agricultural crop in the Netherlands (in the last years between 900,000 – 1,000,000 ha). In the last decades, the grassland area gradually reduced to the present area, mainly due to converting grassland into maize. Furthermore, a lot of grassland was and still is being converted into extension of roads, urban areas, industrial areas and nature conservation areas. The majority of the grasslands is used for dairy production. Part of the grassland area is also utilized by sheep, beef cattle, horses etc.

Grassland can be found on all soil types of the Netherlands: clay, sand, peat and loess. The peat areas, with relatively high ground-water levels (mainly in the western and northern part of the Netherlands), are predominantly used as grassland. Before 1970, the majority of the grassland was permanent grassland, i.e. more than five years old. Rotation of crops hardly occurred. However, during the last 20 years the area with permanent grassland has dropped to about 70%, mainly due to rotation with maize or exchange of land with arable farmers for cultivation of potatoes, flower bulbs etc.

At the moment, on average about 10% of all grassland is resown annually. The actual annual resown area is related to the damage caused by drought or frost. In order to limit N leaching, it is obligatory to resow in spring on sandy soils. For grassland improvement, mainly mixtures of good and productive grass species and varieties are used. There are many mixtures available, which mainly contain perennial ryegrass varieties, both mid-late and late heading. Sometimes timothy and clover seeds are used as well. The use of specific mixtures is increasing, e.g. mixtures for mowing only, for grazing and mowing, with additional structure and with clover. There are also mixtures for sod sowing and/or temporary grassland. Diploid varieties are increasingly being replaced by tetraploid varieties.

Grass yield and grass quality

The temperate maritime climate influenced by the North Sea and the Atlantic Ocean leads to cool summers and moderate winters. Daytime temperatures vary from 2-6°C in winter and 17-20°C in summer. The annual rainfall of 700-800 mm is evenly distributed over the year. These are good conditions for abundant grass growth in the growing season (April – October). Gross yields of 16-18 tonnes dry matter (DM) yr^{-1} are no exception. However, the gross yield (i.e. the grass yield that is grown on the field) is less important than the net yield (i.e. the herbage that is either taken up by the dairy cow or mechanically transported from the field). For determination of net yield, the grazing losses and harvesting losses should be deducted from the gross yield. Aarts *et al*. (2005) estimated the net yield of grasslands in the Netherlands and calculated an average of 10.4 tonnes DM yr^{-1} (9.6 for peaty soils, 10.3 for clay soils, 10.4 for wet sandy soils and 11.5 for dry sandy soils). Variation among farms is large.

Trends in average grass quality during a period of 15 years in the Netherlands are shown in Table 2. Crude protein content and crude ash concentrations of grass decreased during the last years; those of K decreased and Se increased. The decrease coincided with a decreased fertiliser application. The increase in Se content can be explained by the increased use of Se-containing fertilizers (Reijneveld *et al*., 2014).

Table 2. Median values and mean annual change (indicated by slope *b*) of grass quality; grass samples taken from grass silage in the Netherlands. The regression coefficient indicates the mean change of herbage quality per year for the period 1996 – 2009 (Reijneveld *et al*., 2014).

Herbage characteristics[a]	Median	Slope *b*	R^2
Dry Matter	435	n.s.	n.s.
Crude Protein	165	-2.43**	0.52
Crude Fibre	242	n.s.	n.s.
Crude Ash	101	-2.53**	0.69
S	3.0	n.s.	n.s.
P	4.0	n.s.	n.s.
K	35	-0.30*	0.32
Mg	2.4	n.s.	n.s.
Ca	4.7	n.s.	n.s.
Na	2.5	n.s.	n.s.
Se	52	8.33**	0.51

[a] DM in g kg^{-1}, SE in mg kg DM^{-1}, all other in g kg DM^{-1}; * P<0.05, ** P<0.01, n.s. = not significant

Rations

Dairy cattle rations in the Netherlands are in general characterised by relatively large amounts of supplementation, mainly maize silage, grass silage and concentrates. Silage maize is mainly grown on sandy and clay soils. Farms in those areas usually supplement more silage maize than farms in areas where not a lot of maize is produced. During the last decades, the total DM intake from grass has remained relatively stable, but the DM intake from grass silage has increased at the expense of grazed grass. This is partly explained by the fact that the herd size of the dairy farms has increased while the area around the farm that could be grazed has not increased to the same extent.

Fertilisation

The government set rules for storage and application of manure in order to limit NH_3 emission and N leaching to ground and surface water. Amongst others, this means covering of manure storage, changes in method of manure application (sod application or manure injection to reduce emissions) and the period of manure application (during the growing season only) and limits the amount of animal manure per ha. Differentiations were made for various soil types and land use with respect to maximum fertilisation. In addition, standards for use and losses of N and P per ha grassland and ha forage maize were set.

The Netherlands is allowed by the EU derogation arrangement to apply 250 kg N from animal manure per ha grass and forage maize. The total fertilizer standards for the amount of N, and of P as well, have been gradually sharpened during the last years, in particular for those areas with sandy soils where the nitrate content in the ground water still is too high. As a consequence of the maximum amount of animal manure, application of N and P fertilizer sharply decreased in practice. The amount of applied fertilizer P ha^{-1} decreased also (Figure 3). From 2014 onwards due to derogation regulations, application of fertilizer P on grass and forage maize is forbidden.

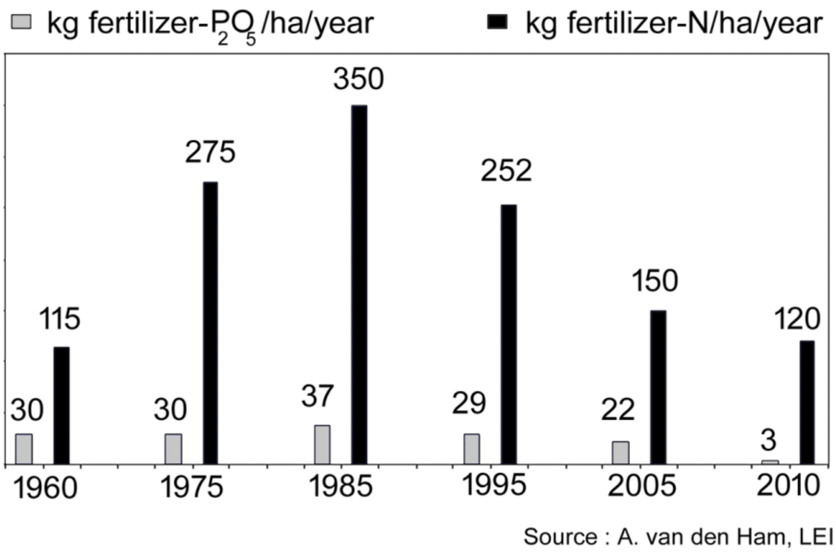

Figure 3. Fertilizer P and N use ha^{-1} grassland yr^{-1} in the Netherlands in the period 1960 – 2010 (Van Dijk *et al*., 2015).

Nutrient losses

High output dairy farming systems in the Netherlands are generally characterised by high fluxes of nitrogen (N) and phosphorus (P) through the systems. These elements cycle through the system by transfer between the components of the farm, i.e. from crops/feed to the herd, from the herd to manure, from manure to soil and from soil to crops/feed. Inadequate nutrient management of these intensive nutrient flows may cause high losses to the environment, which puts the quality of water, air and nature under pressure. Moreover, it reduces resource-use efficiency because not only exports as milk and meat but also losses from the systems are replenished by purchased feeds and fertilisers. From the mid-1980s onwards, an efficient use of fertilisers with minimal losses to the environment was promoted and research efforts were dedicated in that direction.

The experimental farm De Marke was set up with the aim to explore and demonstrate the possibilities to produce milk at an intensity of 12,000 kg milk ha^{-1} without violating strict environmental standards. Optimized mineral management on the pre-designed farming system resulted in a strong reduction of N and P surpluses compared to common practice. In the various management systems that were explored since 1993, N surpluses at farm level amounted to 98-165 kg ha^{-1}. P surpluses ranged from 0-6 kg ha^{-1} (Verloop, 2013). In the project 'Cows & Opportunities' the research on improvement of nutrient management was extended to commercial dairy farms on various soil types (Oenema, 2013).

The research has led to a strong decrease in mineral losses to the environment in practice in the years thereafter. Moreover, it led to more insight into the flows of minerals at farm level and to the development of practical tools for farmers. For example, in the Netherlands the model ANCA (Annual Nutrient Cycle Assessment) was developed (Aarts *et al*., 2015) to provide insight to farmers into the impact of their management on the functioning of nutrient cycles. From 2015 onwards, ANCA serves as a licence-to-produce for the dairy farms in the Netherlands with a manure surplus (which is about 70% of the number of farms). It ensures that losses are minimised as much as possible.

Trends in grazing

Grazing of dairy cows has several advantages, like more possibilities to express natural behaviour of dairy cows and the contribution to the image of the dairy sector, but also disadvantages, like more nitrate leaching and a less balanced diet (Van den Pol-van Dasselaar *et al*., 2008; Hennessy *et al.*, 2015). It even affects the quality of the milk, since grazing increases the levels of unsaturated fatty acids in milk and meat (e.g. Elgersma *et al*., 2006). The percentage of dairy cattle with grazing has been decreasing from 90% in 2001 to 65% in 2015, but recently it increased again (Figure 4).

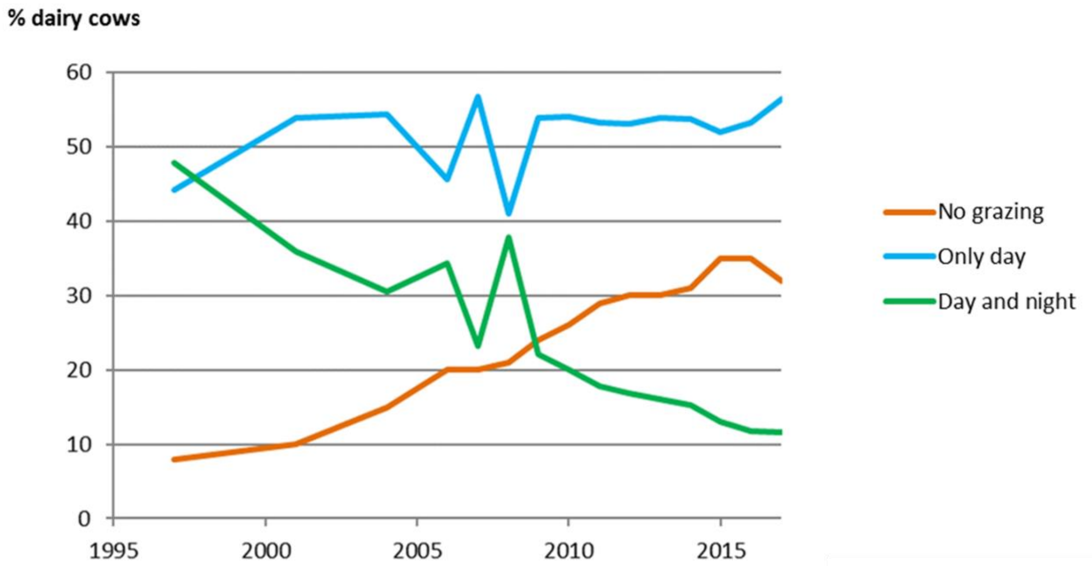

Figure 4. Grazing, % of dairy cows in the Netherlands in the period 1997 – 2017 (CBS, 2018).

Grazing is not evenly distributed over the Netherlands (Figure 5). In general, there is less grazing in the south and the east of the Netherlands.

Reasons for the decrease in grazing between 2000 and 2015 in the Netherlands were:

- To control rations and optimise grassland utilisation (when fed on grass only, DM intake is enough to meet requirements of maintenance and milk production of 22-28 kg milk per day per cow)
- Grazing platform that does not increase, while herd size increases (see Figure 6; Figure 6 also shows an increasing percentage of grazing for larger herds in the last few years)
- Increased use of automated milking systems
- Grazing “doesn’t sell” (when cows are fully housed, more machinery and concentrates are needed)
- Need to reduce mineral losses
- Labour efficiency

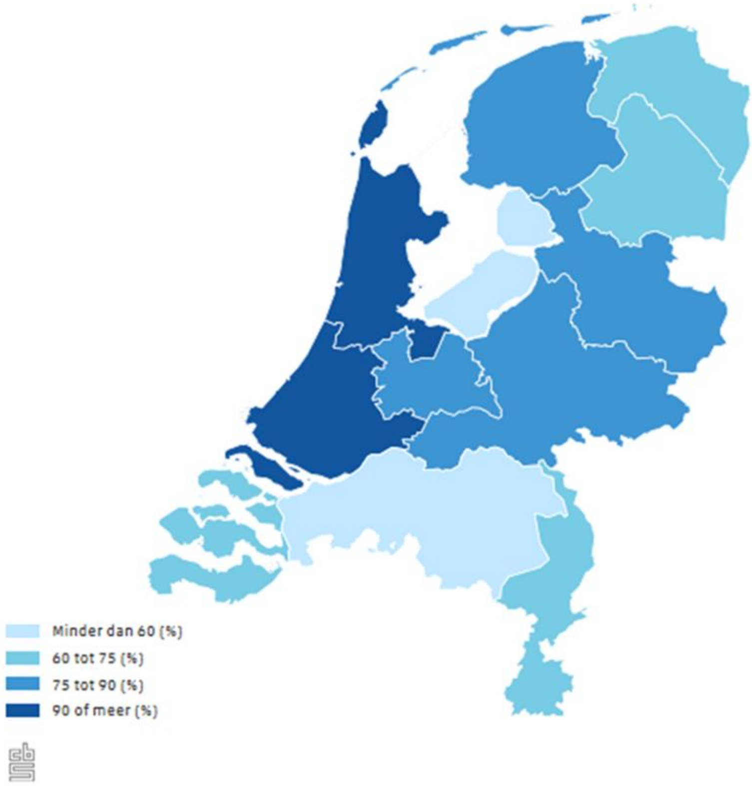

Figure 5. Grazing in different parts of the Netherlands (CBS, 2018).

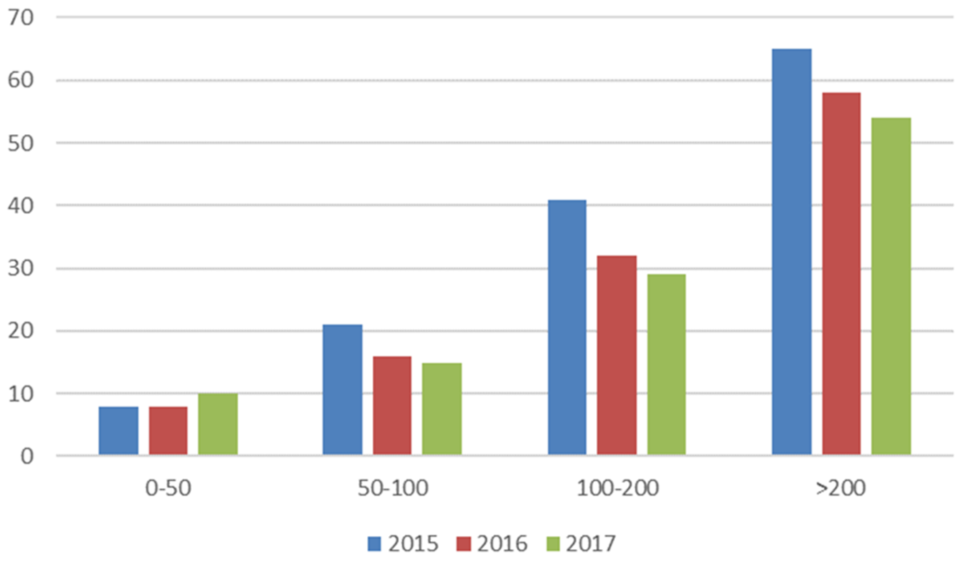

Figure 6. Effect of herd size on zero-grazing in 2015, 2016 and 2017. Larger herds increased their percentage grazing in the last years (CBS, 2018).

Grazing as a societal issue and grazing premium

During the last decade the decrease in grazing has become a societal issue in the Netherlands. In Dutch politics and society, there is a broad interest to promote cows having access to pasture. Public debates emphasize the high perceived-value of grazing for animal welfare. The grazing cow is even seen as an icon of the Netherlands and part of the cultural heritage. The Dutch society has expressed its concern about less grazing. As a consequence, in 2012 a voluntary agreement, the 'Treaty Grazing', was signed (Figure 7) by many partners in the Netherlands with the aim of stabilising the percentage of dairy farms that practise grazing. By now, around 83 parties have signed the agreement indicating the importance of grazing in the Netherlands. Among the parties signed are representatives of dairy farmers' associations, dairy industry, feed industry, milk robot industry, banks, accountants, semen industry, veterinarians, cheese sellers, retail, NGOs, nature conservation, government, education and science. As part of the Treaty, many stimulating initiatives took place. The most prominent one was the introduction of a grazing premium of 1-2 cents per kg that is provided by the dairy industry to farmers that practise grazing for at least 120 days per year for at least six hours per day. 'Pasture milk' is processed in separate milk streams and the majority of the Dutch supermarkets only sell such milk.

Grazing became an issue even in parliament in 2017 when a number of political parties suggested the requirement to make grazing obligatory. Other parties were confident that the 'Treaty on Grazing' would prevent a further decrease in grazing and, as such, the Treaty prevented the obligation. At the end of 2018, it was shown that the percentage of dairy farms with grazing is increasing, which is seen as a success for the Treaty (Duurzame Zuivelketen, 2018) (Figure 8).

Figure 7. Signing of the 'Treaty Grazing'; Source: Duurzame Zuivelketen.

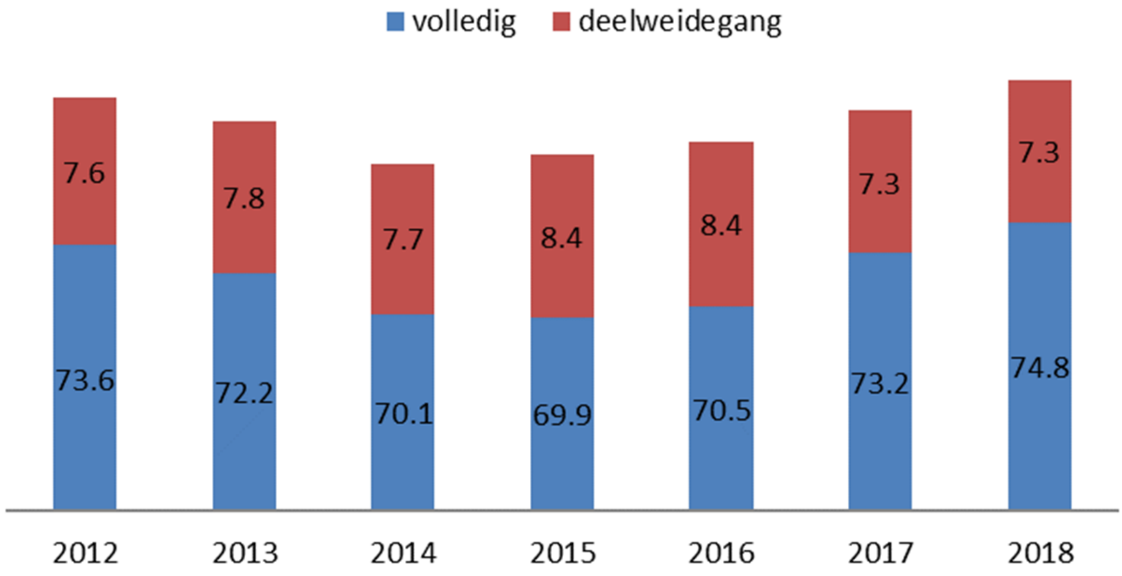

Figure 8 . Percentage of Dutch dairy farms that practise full grazing (in blue; at least 120 days of grazing and 720 hours of grazing per year) and partial grazing (in red) (Duurzame Zuivelketen, 2018)

<u>Grazing systems</u>

For cattle, various grazing systems can be applied that vary in:

- Number of hours grazing per day
  - Day and night grazing
  - Grazing only during day time, housing at night, feeding additional maize or grass silage and sometimes fresh grass (majority of Dutch farms)
- Number of days grazing per paddock
  - Rotational grazing: cows get regularly a new plot for grazing, varying from once or twice a day to each 2-6 days
  - Continuous grazing: cows graze for a longer period of time (3-6 weeks to months) on a large paddock. The grass allowance of the paddock can be kept relatively stable by adapting the land area or by supplemental feeding.

Dutch dairy farmers mainly practise rotational grazing. However, continuous stocking is increasing. Recent trends are:

- Shortening the period of grazing on one plot for rotational grazing to 1-2 days per plot
- Introduction of compartmented continuous grazing on many farms

Compartmented continuous grazing ("*Nieuw Nederlands Weiden*" in Dutch) is an adapted set-stocking system for stocking rates up to 10 animals per ha in which the cows rotate on a daily basis between six compartments on one platform. Each day, cows are moved to a new compartment and in a period of 5-6 days, they rotate on five or six compartments. The (variable) sixth compartment is cut for silage to increase sward utilisation. So, cows come back in the same compartment after 5-6 days. The average grass height in the compartments is kept constant (8-12 cm) so that daily regrowth is available for intake. The gap between daily regrowth and animal demand is filled with supplementation.

The grazing system was developed a few years ago in the Netherlands as a system that combines high grazing efficiency with ease of labour in dairy systems that have a high stocking rate and a high milk production per cow. The system is easy to implement, can be done on every farm, does not require a lot of labour / management skills and gives good result with respect to milk production and grass utilisation. The area on the farm that is available for grazing will be optimally used with this grazing system.

Next to grazing, farmers can keep their cows inside for the whole summer and feed them freshly cut grass (zero-grazing) or silage (summer feeding). Various combinations of systems can be found in practice as well. Each of the systems has pros and cons. The best system for a certain farm mainly depends on the infrastructure of the farm, available man-power, number of cows, stocking rate and allocation of grassland. The best system can also change during the year. Consistent management is important for all grazing systems.

<u>Ensiling grass</u>

In the course of the years various silage making systems have been practised. In the last 10-15 years, 85-90% of all grass cut for winter forage has been ensiled, mainly as wilted silage. After a field period of 2 to 3 days the grass is ensiled at a dry matter content of 35 to 45%. Wilting leads to a higher osmotic pressure in the grass cells which inhibits unwanted bacteria to develop in the silage. Wilting appeared to be the best and cheapest conservation method for young, protein-rich grass. Basically, for this ensiling method, additives are not needed and there are no problems with environmental pollution caused by silage effluent, while intake of the silage by cattle is quite good. However, a quick ensiling is important (preferably in one day) just as an air-tight silage storage.

Silage additives are used to a limited extent. In the past mostly acids, salts or molasses were applied. In recent years mainly mixtures of bacteria are used. Additives are applied only if less-good conservation results are expected, for instance when the grass is not sufficiently dry, high in protein or low in sugars, or when the field period lasted too long. High dry matter silages can heat up when they are opened. Prevention of this problem is possible: sufficient compaction during ensiling, correct airtight storage and sufficiently rapid feeding of the silage. There are also special mixtures of bacteria that can restrict heating of the silage. Such mixtures are used in practice on a limited scale. Overall, 5-10% of wilted silages are treated with bacteria. Chopping of grass has a positive effect on the preservation and density of the silage due to the bruising and mixing during chopping.

Ensiling large bales (both round and rectangular, both with and without plastic covering) also became popular in the Netherlands. It is estimated that 15-25% of grass is ensiled in this way. The method is particularly attractive to store special lots separately and in case silage needs to be sold. In addition, it is not necessary to immediately transport the bales to the storage yard after pressing and wrapping them.

Many farms still use their own machinery for harvesting activities. However, increasingly, contract workers are involved, who take care of loading and transport. Contract workers have available large forage wagons, choppers and balers and can execute all the activities at reasonable costs per ha. In general, contracting costs are lower than the farmer’s own mechanisation costs.

Today, most silage is stored in large clamps on concrete surfaces or in bunker silos. In particular, the number of large bunker silos has increased during the last years. Advantages of those silos are the limited investments, correct storage and various machinery available for filling the silo and removing the silage.

Outlook on the future of dairy systems in the Netherlands

An integrative approach for grassland management that is cost effective, environmentally sound and manageable is essential in the context of the development of large-scale dairy enterprises with highly productive healthy animals. New functions of high output dairy farming systems arise with corresponding revenue models, e.g. energy production, emission trading, and provision of other ecosystem services like cultural services. A diversity of dairy farming systems may develop. Van den Pol-van Dasselaar *et al*. (2014) showed in a survey with approximately 2000 respondents from different countries of Europe (mainly from Ireland, France, Belgium, the Netherlands, Poland and Italy) that the individual functions of grasslands, like grazing, biodiversity, carbon sequestration, low-cost feed, landscape etc., are highly recognized and appreciated by all relevant stakeholder groups in Europe. All stakeholders considered that the large European grassland area is a valuable resource which is essential for the economy, environment and people. This could be exploited.

Further development of the dairy sector will require continuous development of people (education, training), tools (e.g. decision support systems) and techniques (innovations like sensors at cow and field level or techniques for manure refining). These developments are taking place in practice. Grasslands will remain an essential part of dairy farming systems, producing feed for the dairy cattle. Grass production and utilisation should be stimulated by good grassland management, managing constraining factors like water shortage and using highly productive grass varieties and legumes. Soil (fertility) data, together with fertilization registration, grass growth, weather data etc., collected at different resolutions, scales, time, and together with historical data could all be integrated in decision support systems. Multiple layers of information need to be analysed and assessed. This data assessment, evidently, needs to increase grassland yield, improve herbage quality and ensure a prudent use of nutrients. It is also essential to increase the net yields of grazed pastures by reducing the grazing losses (trampling, urine and faeces) and by developing novel grazing systems for future dairy farms (large-scale, high productive, highly automated) that are technically and socially feasible and are economically viable and environmentally sound. The potential to improve the grass yield is enormous as can be seen by the current variation in grass yield in practice. Optimal use of grassland will lead to profitable farming with minimised environmental impact while addressing demands from society like animal welfare and grazing.

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7.4 Belgium

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This section is largely based on the following publication:
Peeters A., 2010. Country Pasture Forage Resource Profile: Belgium. Food and Agriculture Organisation of the United Nations (FAO): 75 pp.
However, this text has been fundamentally revised, completed and updated.

1. GENERAL INFORMATION

Land area and land structure

In Belgium, agriculture occupies almost 60% of the land mass, woodland about 20% and urban areas, including residential, industrial and green areas as well as communication ways, about 20% (table 1). There was a continuous decrease of the Agricultural Area (AA) to the benefit of urban areas since the 19th century. The permanent grassland area increased a lot in the 2nd half of the 19th century, but it decreased slightly after the 1970s and it is still decreasing.

Table 1. Land use in Belgium and evolution between 1834 and 2017 (FPS Economy, 2008; FPS Economy - DGSEI, 2009, Statbel, 2018).

	1834	**1990**	**2000**	**2007**	**2017**
	km²	**km²**	**km²**	**km²**	**km²**
Land area	29 456	30 278	30 278	30 278	30 278
Agricultural area	19 172	18 302	17 653	13 703	13 292
Arable land	15 087	7 594	8 631	8 396	8 357
Permanent grassland	3 468	5 786	5 069	5 073	4 678

Socio-economic and structural aspects of agriculture

There were about 35,900 farms in Belgium in 2017. Two thirds were located in the Flemish region, one third in the Walloon Region. Farms are more than twice larger in Wallonia (57 ha) compared to Flanders (26 ha). In Wallonia, the industrial revolution began early in the 19th century which created jobs outside the agricultural sector and induced a manpower transfer from agriculture to industry (coal mines and steel factories at that time). That permitted a faster farm size increase compared with Flanders where the industrial revolution started only in the middle of the 20th century. Flemish farmers had to intensify their production if they wanted to survive on their small farms in this densely populated region. In the second half of the 20th century, they specialised in flower, vegetable, pig, poultry or dairy productions. These productions, especially the four first types, can provide significant incomes on very small surfaces. In Wallonia, the lack of space was less critical; farms specialized in cereals, sugar beet, beef and dairy productions. The two development models are thus radically different. Most Belgian farms (about three quarters) have permanent grasslands, the half have forage crops and/or cattle.

The sector accounts for a bit more than 0.5% of the Belgian GDP in 2017 (Statbel, 2018) but it has a more significant importance when the up-stream (ex.: machinery, fertilizer and pesticide productions) and down-stream (ex.: mill and sugar industry, abattoirs, animal feeding and dairy industries) sectors are considered. The economic importance of the total chain is often estimated at about 10% of the GDP (FPS Economy, 2007). When considering exports, the whole agricultural sector (animal and plant products, food products, drinks and tobacco) represented 11.8% of the Belgian GDP in 2017 (Statbel, 2018).

Photo 1. Flemish plain. Left: Grasslands, avenue of poplars (*Populus*) and some pollarded willows (*Salix alba*). Right: Old pollarded willows (Salix alba). Source: ILVO - Merelbeke.

Photo 2. Ardenne. Left: Plateau with a village, grassland plots, arable land (in the background) and farm buildings (in the foreground). Middle: Temporary grassland (grass/clover mixture) managed by cutting for making haylage or silage. Right: Belgian Blue cows grazing. Spruce (Picea excelsa) forest in the background. Source: S. Cremer.

2. RUMINANT LIVESTOCK PRODUCTION SYSTEMS

Recent history and context

In dairy systems, from an average annual production of 4,500 l per cow in the 1970s, the production increased to 7,800 l/cow in about 35 years, while some herds or some cows are reaching now an annual production of 10,000 to 12,000 l/cow. This regular increase of dairy performances of about 1.3% per year was possible thanks to an international breeding effort of the Holstein-Friesian breed. That led to a decrease of the populations of many dual-purpose breeds (e.g. Red of the Flanders, Red and White, dual-purpose Belgian Blue). Yield increases induced also changes in animal feeding. More concentrates were used at the expense of the proportion of green forages. The implementation of milk quotas slowed down this trend because the control of the volume of production required a decrease of production costs. This was achieved by a better utilisation of green forage that are less expensive than concentrates. Values of 3,000 to 4,500 litres of milk per cow and per year are regularly obtained on the basis of green forage (forage maize and grassland). The decrease of production costs was also achieved by a higher production per cow. The milk quota of each farm has been fulfilled with a decreasing number of cows. That decreased the proportion of maintenance feeding needs and increased the proportion of production needs in the total feeding costs. The CAP reforms of 1992 and 2000, induced a significant decrease of cereal grain price (about 50%) and that encouraged again dairy farmers to use this product in animal feeding. Moreover, farmers tended to use more maize silage at the expense of grass grazing and grass silage when dairy cow production is above a certain threshold (roughly above 6,000 l/cow). They did not trust grass quality and grass intake potential of their high-yielding cows especially by rainy weather and unfavourable temperatures. They tend thus to keep partially cows indoors or to complement systematically grassland grazing with maize silage. That led to a decrease of grassland proportion in the Agricultural Area. This trend was very strong in Flanders (Polders, Sandy Region, Sandy-Loamy Region, Kempen). In the Grassland Regions of the South East of the country, the strategy of farmers was a bit different; they used less maize but increased concentrate use. They also tried to reduce production costs by a better use of grazing and grass silage.

In beef production systems, the Belgian Blue emerged as the almost only profitable breed in the 1970s. Grazing remained the basis of suckling cow systems and animals were fed in winter mainly with hay and haylage. Concentrates and maize silage were restricted mainly to bull fattening. Ox fattening disappeared almost in favour of young bulls.

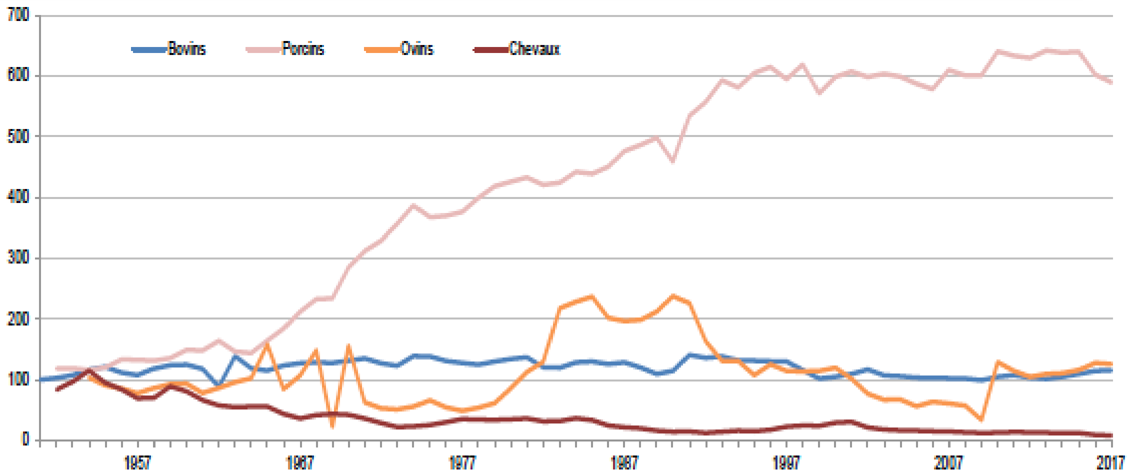
All these system changes had impacts on landscape and wildlife by reducing diversity and complexity. Farmers had to face criticisms for their negative effect on the quality of ground- and surface-waters. Measures had to be taken to decrease nitrate and phosphate pollution. Farmers had also to respect the Habitat and Bird Directives but that represents only a small part of the Agricultural Area in Belgium. The Nitrate Directive was also mandatory for farmers. It had a significant influence on farm structures and practices of intensive livestock systems by regulating the stocking rate and the management of organic nitrogen. The agro-environmental measures gave the opportunity to farmers to adopt concrete measures that can improve their impact on the environment.

In summary, the successive EU CAP reforms led to ‘modernisation’ of the sector, farm size increase, a dramatic farmer’s population decline, specialisation of productions, intensification of grassland and animal husbandry, increase of the volume of production, increase of grassland and animal yields, reduction in legume use, reduction in grassland area and its proportion in the Agricultural Area, reduction in the diversity of landscape, grassland species and communities, and domestic animal breeds. The implementation of milk quotas reduced the number of dairy cows which induced a stocking rate decrease in some cases or the development of beef production systems in complement to dairy systems in most cases.

Animal sector as a whole

Belgian agriculture is strongly oriented to meat and dairy productions. Between 1997 and 2007, there has been a decrease of beef meat production and an increase of pork meat production. Milk production has been fairly constant, due to EU milk quotas restricting production. However, after the phasing out of the milk quotas, the total milk production of the country increased again between 2007 and 2017 from about 3,000 to about 4,000 million litres (Statbel, 2018).

Since 1990, the number of animals decreased for cattle and sheep and increased for pigs and poultry. Figure 1 shows the spectacular increase of pig populations, the stability of cattle and sheep populations and the decline of horses between 1951 and 2017. All species numbers increased per farm. Between 1990 and 2004, these animal numbers per farm evolved from 56 to 86 heads for cattle, from 332 to 785 heads for pigs and from 1,851 to 6,575 heads for poultry (Genot, 2005).



Legend: Bovins = cattle; Porcins = pigs; Ovins = Sheep; Chevaux = horses.
Figure 1. Evolution of the number of slaughtered animals (%) (1951-2017) (1951 = 100) (Statbel, 2018).

Intensification levels of livestock production can be defined by stocking rate *i.e.* the ratio between Livestock Units (LU) and the surface (ha) of grassland and forage crops. In Belgium, they are considered as ‘medium’ (1.6 ≤ stocking rate < 3) for cattle and sheep and ‘high’ or ‘very high’ (high: 3 ≤ stocking rate < 7; very high: stocking rate ≥ 7) for pig and poultry. Compared with the European average, even cattle and sheep intensification levels are high or very high.

Dairy farming is traditionally concentrated in Lower and Central Belgium as well as in the Liège Grassland Region and Upper Ardenne. The Sandy Region, the Sandy-Loamy Region, the Loamy Region, the Kempen and the Liège Grassland Region include almost 80% of the national dairy cow population. Suckling cows are concentrated in Central and Higher Belgium (Namur and Luxemburg provinces). The

Sandy-Loamy Region, the Loamy Region, the Condroz, the Famenne, the Ardenne and the Jurassic Region include about 80% of the national suckling cow population. Dairy cows are thus more abundant in the North and the West of the country, suckling cows in the South and the East. Most dairy cows are bred at low altitude. In higher altitudes, suckling cows are dominant. The Atlantic climate of the Flemish plain and the Kempen creates very favourable conditions for dairy production because it provides good grass-growing conditions: a relatively regular growth throughout a prolonged growing season.

Photo 3. Dairy breeds in the Flemish plain. Left: Red and White cows by a canal. Right: Holstein cows in an urbanized landscape with poplar (*Populus*) plantations. Source: ILVO - Merelbeke.

Dairy production

Dairy cow herd size is typically 50 in specialized farms (Statbel, 2018). The national average production per cow does not make a lot of sense in Belgium. It hides a huge variability of dairy performances between dual-purpose Belgian Blue cows that produce annually about 3,000 l/cow, dual-purpose Red and White cows that yield annually about 4,500 l/cow and specialized dairy Holstein-Friesian cows that produce much more. In 2017, average annual milk production per specialized dairy cow was 7,800 l and average values for milk fat and protein contents were 4.09% and 3.45%.

A high-yielding dairy cow ingests in practice about 1,000 to 1,500 kg concentrate per year. With regard to green forages, the proportion of green grass, grass silage and maize silage in the diet varies a lot according to farming systems and regions. Winter housing is either a free-stall with a slatted-floor and a milking parlour, either a tie-stall where milking is carried out in cow individual stall. The first type of building is slurry-based, the second one farmyard manure-based. Straw free-stall systems are developing. Dairy farms are usually smaller than beef farms. Their income per ha is higher.

Beef production

Beef cattle herd size varies considerably according to regions and farming systems. Beef farms have about 30 suckling cows in average (2017) (Statbel, 2018). Mating is mostly natural in beef production. During the grazing period, each suckling cow herd of a farm includes one or several reproduction bulls including in the herd of the tallest heifers. The calving period is concentrated between December and March. Male and female calves suckle their mother that produces about 1,000 to 2,000 litres per year.

Winter housing is either a free-stall or a tie-stall. Both are bedded with straw and produce FYM. In tie-stalls, calves are kept in pens and have access to their mother a limited time per day. There is an increasing trend to separate calves and cows after calving in Belgian Blue systems. Young bulls never graze in this system since they are kept indoors up to the end of the fattening period just before slaughter. In traditional systems, cows and calves start grazing together in April-May. Calves drink milk, graze and have access to a feeding system for receiving concentrates in grassland. Cows only graze.

Sheep and other ruminant productions

Sheep are raised in small numbers (about 151,000 in total in 2007) mainly for meat production. Sheep breeding is often a secondary or a hobby activity. Sheep are often kept indoors during winter time. Lambing is concentrated between February and April for the production of ‘herbage lambs’ or ‘grey lambs’. In this case, ewes and lambs graze together from April to August or September. Lambs can receive concentrates in grassland for a short period before slaughter at the end of summer. Dry ewes graze till the middle of November. In this system, lambing occurs indoors in December – January. Lambs can suckle ewes and they receive also concentrates. They are slaughtered when they are three months old, in April. They thus never graze. Ewes are grazing alone from April to November.

There were about 29,000 goats only in 2007. Among the curiosities in this part of Europe, American bison and red deer can be cited. Most bisons are raised in Wallonia, in the Ardennes, and most deers in Flanders.

Organic farming and stockbreeding

In the Flemish Region, in 2017, the area under organic farming was 7,367 ha (Statbel, 2018). This area corresponds to only 1.2% of the total Agricultural Area in Flanders. The same year, there were 468 Flemish organic farmers. Several socio-economic factors underpin the low development of organic farming in Flanders. Firstly, organic farmers have experienced difficulties in marketing their products. Secondly, traditional farmer’s advisory circuits did not support organic farming.

In the Walloon Region, the number of organic farms and their total agricultural area are much more on the rise, especially since 1996 (Statbel, 2018). At the end of 2017, organic farming covered 76,072 ha, or 10.6% of the Walloon Agricultural Area. This proportion is higher than the EU-15 average: 7% of the Agricultural Area in 2017 (Eurostat 2018). The same year, there were 1,625 organic farms in Wallonia. It is about 3.5 times more than in Flanders. In 2017, 78% of Belgian organic farms and 91% of Belgian organic agricultural area were located in the Walloon Region.

3. THE PASTURE RESOURCES

Forage production systems

There are two main forage production systems in Belgium. The Flemish system is based on regularly resown grasslands and on annual forage crops (temporary grasslands and maize). The system of Wallonia is mainly based on permanent grasslands. Interestingly, the highest proportions of grasslands in the Agricultural Area are mainly observed in low human density areas (Provinces of Luxemburg, Namur and Liège).

Grasslands and forage crops

Table 2 summarizes typical Belgian yields of forage maize and fodder beet, compared to intensive cutting temporary grasslands and grazed permanent grasslands.

Table 2. Comparison of typical yields of the main forage crops in Belgium (Deprez *et al.*, 2007).

	Forage maize	Fodder beet	Cutting temporary grassland	Grazed permanent grassland
t FM/ha	50	120	50	57
%DM	30	13-19	20-30	15-20
t DM/ha	13-18	14-21	12-16	8-12

Legend: FM = fresh matter; DM = dry matter.

Permanent grasslands

Agriculturally-improved permanent grasslands include 15 to 20 species of higher plants on 1 ha, *i.e.* about 10 species on 100 m^2. Among those, grasses are dominant. The most common are: *Agrostis stolonifera* (on fresh and wet soils), *Alopecurus pratensis* (on fresh and wet soils), *Dactylis glomerata, Holcus lanatus, Lolium perenne, Poa pratensis* (especially on superficial or sandy soils that are dry during a part of the growing season), *P. trivialis*. Some nitrophilous dicotyledons can be locally abundant: *Cirsium* spp., *Ranuculus repens, Rumex crispus*, *R. obtusifolius, Stellaria media*, *Taraxacum* spp. (especially in the Ardennes) and *Urtica* spp.. *R. obtusifolius* is the main grassland weed. *Cirsium arvense* and *Urtica dioica* can be locally problematic too. The proportion of *Trifolium repens* in swards is usually low but it can be important when the defoliation frequency is high and usually when the nitrogen fertilization is not too important. Other legume species are rare in intensively used permanent grasslands.

Photo 4. Grasses and legumes. Left: Perennial ryegrass (*Lolium perenne*) - white clover (*Trifolium repens*) mixture. Right: Perennial ryegrass (Lolium perenne) spikes. Source: ILVO - Merelbeke.

Photo 5. Legumes and grasses Left: Red clover (*Trifolium pratense*). Right: Grass – Lucerne (*Medicago sativa*) mixture. Source: ILVO - Merelbeke.

Photo 6. Species-rich cutting meadow in a nature reserve. Source: S. Rouxhet.

Temporary grasslands

Temporary grasslands can be mainly cut (1 hay cut and aftermath grazing or 2 to 3 silage cuts + grazing or 3 to 4 silage cuts), or mainly grazed (grazing only or grazing + 1-2 silage cuts). Typical cutting temporary grasslands are sown for 1 to 5 years. In recent years, they tend to be kept for a longer period especially in grassland specialized regions of the South-East of the country. In the Flemish Region, between 1960 and 1990, mainly grazed temporary grasslands were established for about 5 years and re-sown on their self. After 1990, there has also been a trend to convert them in permanent grasslands with or without regular over-sowing.

Mixtures for mainly cut grasslands include 1 to 5 species. The most widespread species are *Lolium perenne* and *L. multiflorum* (about 90% of the seed market). Other sown species are grasses: *Dactylis glomerata*, *Festuca pratensis*, *F. arundinacea*, *Phleum pratense*, *Poa pratensis*, hybrids of *Lolium* spp. and sometimes *Lolium* x *Festuca*; and legumes: *Medicago sativa*, *Trifolium pratense*, *T. repens*. In the Ardennes, a traditional mixture includes *F. pratensis*, *L. perenne, P. pratense* and *T. pratense.* The frost resistance of *F. pratensis* and *P. pratense* is appreciated above 500 m asl. These species are added in this mixture as an insurance against climatic accidents. Simple mixtures of *L. perenne* usually pure or in mixture with *T. pratense* and/or *T. repens*, and simple mixtures of *L. multiflorum* mixed or not with *T. pratense* are the most frequent for the establishment of grasslands harvested for silage making. The mixture of *D. glomerata* and *Medicago sativa* was almost abandoned in the second half of the 20th century but recently its potential is recognized again by farmers from Low and Central Belgium, as well as those from Condroz and the Jurassic Region.

Legumes in grassland swards

Trifolium pratense, *T. repens* and *Medicago sativa* are the three main forage legume species in Belgium. *T. pratense* and *M. sativa* are almost exclusively used in cutting temporary grasslands. *T. repens* is mainly used for the sowing of long-lived grazed swards but its large size cultivars are also sometimes associated to medium-lived cutting mixtures. The capacity of N fixation and the high nutritive value and intake potential of these three legume species are increasingly appreciated by farmers after a long memory lapse. Both characteristics can reduce production costs and thus increase farmer's income. Surfaces devoted to the cropping of clovers and lucerne decreased dramatically since the 1960s in Belgium. They still decreased, respectively, by 69% and 26% between 1990 and 2000 (DGSEI, 1990 and 2000). Belgian farmers acknowledge the theoretical interest of legumes, but in their intensive grassland production systems, they tend to prefer the use of nitrogen fertilization that provides important and regular yields, even if it leads to sacrifice legumes. This practice has been maintained by the relatively low prices of nitrogen fertilizers and by some drawbacks of legume species. Despite undeniable breeding progress, persistence remains a problem, especially for *T. pratense*. A slow growth and a low nitrogen fixation in spring make grass/clovers, especially grass/*T. repens*, mixture less attractive than N fertilised pure grass swards. Despite a low mortality rate, bloat risk induced by *T. repens* in grazed swards is often overestimated by farmers.

Grassland management and forage conservation

Grassland management systems are quite diverse in Belgium though intensive almost everywhere.

Temporary or permanent grasslands

In the Flemish Region, grazed and mixed used grasslands are traditionally resown, mostly on the same place, every 4-5 years. One fourth or one fifth of the grassland area of a farm is renovated at the end of summer by this technique. This system is still important in this region but there is a clear trend to increase the lifetime of the sward and to use more permanent grasslands.

In the Walloon Region, grassland production is mainly based on permanent swards. The most intensive dairy producers of the Herve country and the Upper Ardennes prefer also to keep permanent grasslands, but they try to improve their botanical composition by the introduction of *Lolium perenne* seeds.

Temporary grasslands that are used for the production of conserved forages, normally take part in crop rotations. In Lower and Central Belgium, these short- and medium-lived swards are sown either with *Lolium perenne* for 3-4 years, either with *L. multiflorum* for one (ssp. *Westerwoldicum*) or 2 years (ssp. *multiflorum*). Mixtures are usually composed of several cultivars. Early cultivars of *L. perenne* are appreciated for silage making. They are mixed with intermediate cultivars especially if the sward is sometimes grazed. Hybrid ryegrasses (*L. perenne* x *L. multiflorum*) are sometimes used for trying to combine the persistence and the excellent feeding quality of *L. perenne* with the high yielding potential of *L. multiflorum*. In the last 40 years of the 20th century, the use of grass/legume mixtures declined a lot but, in the beginning of the 21th century, there is a renewed interest for these types of mixtures, especially for *Medicago sativa* and its mixture with *Dactylis glomerata*. Some farmers understood that these forages are cheap sources of quality protein and that they can reduce fertiliser costs with biologically nitrogen fixation.

Fertilization

Nitrogen fertilization is high in all regions though limited by law. On the whole territory of the Flemish Region, organic N fertilization from animal manure is limited to 170 kg/ha on grassland and most crops. The total mineral and organic nitrogen application must always be lower than 350 kg/ha per year on grassland, but no N fertilization is allowed on forage legumes (125 to 275 kg/ha on arable land). On the whole territory of the Walloon Region, organic N fertilization is limited on grassland to 230 kg/ha per year (115 kg/ha on arable land). The total mineral and organic nitrogen application must always be lower than 350 kg/ha per year on grassland (250 kg/ha on arable land).

The responsibility of farming in the nitrate pollution of water tables has been frequently estimated at more than 80%. Farming in general and stockbreeding in particular are also responsible of emissions of NH_3 and N_20 in the atmosphere. The deposition of ammoniac in oligotrophic habitats like moorland, peatland and forests induces the eutrophication of these habitats and the disappearance of rare oligotrophic species. The entire functioning of these, sometimes threatened, habitats is disturbed because of these excessive N inputs from the atmosphere. In average, annual N deposition increased in Belgium from about 5 kg/ha in the 19th century to about 35 kg/ha at the end of the 20th century. In some areas of the Flemish Region, this annual N deposit reaches 50-80 kg/ha. N_20 is emitted mainly by wet and trampled N-fertilized grassland soils. It is a greenhouse gas that is responsible of climate change.

Phosphorus fertilization was also overestimated during the 30-40 years of the ‘blind intensification period’. Many Flemish soils are saturated by phosphorus and P leaching is even observed on sandy, easily leachable soils. On the loamy soils of

Wallonia, P leaching does not usually occur, but many soils are so rich in P that the cessation of P fertilisation during 20 years in experiments did not lead to yield reductions. Surface waters are though polluted by soil phosphate run-off of mineral and organic P in both regions. That induces eutrophication of rivers and the reduction of aquatic biodiversity.

It has been calculated that P and K fertilisation is no more necessary on grasslands in dairy farms because inputs of these nutrients by concentrates are sufficient for compensating the outputs by meat and milk if the nutrient cycle of these chemical elements through spreading of slurry, urine and dung deposits during the grazing period is well managed. In specialized cutting grasslands, exports of P and K by forage harvesting for conservation are important. They are more and more compensated by a concentration of organic manure application on this type of swards. In conventional farming, N fertilizers are still used on grasslands (except on well managed grass/legume swards) but even the use of this nutrient has been strongly reduced by better information of farmers on the fertilization value of organic manures. These manures were too often considered as wastes during the 1960-1990 period, their fertilisation value was not taken into account. That led to an overuse of chemical N fertilization and pollutions of the water tables and surface waters by nitrate. The European Nitrate Directive helped a lot for stimulating farmers to calculating precisely the N balance in their farms and the N requirements of grassland plants. As a result, N and P fertilizations were significantly reduced in the last 10 years.

A dense network of laboratories of soil analysis provides fertilization advices to farmers who call upon their services. In Wallonia, these laboratories are strongly subsidized by public authorities.

Production

Belgium is one of the areas of Europe where grassland production is the highest without irrigation (Peeters & Kopec, 1996). In cutting experiments (3-4 cuts/year), annual yields of *Lolium perenne* are about 12-16 t DM/ha in Lower and Central Belgium (10-14 t DM/ha in Ardenne). Annual yields of *L. multiflorum* are about 15-20 t DM/ha in Lower and Central Belgium (12-16 t DM/ha in Ardenne). In a frequent defoliation regime (4-week interval between cuts), average annual yields of about 9 t DM/ha were recorded in the Ardennes (Peeters & Kopec, 1996). In farm conditions, annual yields of grazed swards are typically ranging between 6-12 t DM/ha. In Lower and Central Belgium, annual yields of 10-12 t DM/ha are not rare in grazed swards.

The average stocking rate is about 2.4 LU/ha of the forage area (temporary and permanent grasslands + forage maize) in the Walloon Region and about 3.2 LU/ha in the Flemish Region.

Grazing systems

Grazing systems evolved very much over time. They could be sometimes quite complex in the 1960s; they are now much simpler. Strip grazing was used in permanent grasslands, for grazing forage crops established for a short period of some weeks between two main crops and for grazing longer-term temporary grasslands. This system though effective is now rare because it requires a high labour input. Rotational grazing was the reference system in the 1960s and the

1970s. Mineral nitrogen fertilization increased progressively since the 1960s. Silage cuts were generalized in this system in the 1970s. At the same period, the intensive set stocking system was promoted. It was associated to higher nitrogen fertilization levels compared to rotational grazing. In the 1960s, many farmers were afraid to spread mineral N fertilizers in the presence of cows in a paddock, but they understood quickly that this technique was safe. Most systems are now intermediate between pure rotational systems including about 10 paddocks for the dairy cowherd and pure set-stocking systems with a single paddock. These intermediate systems are a way for farmers to combine the advantages of both systems. They try to minimize labour like in set stocking systems and to optimize the flexibility of management that is characteristic of rotational grazing systems.

In dairy systems, the number of paddocks for dairy cows typically ranges from 1 to 5 in Lower and Central Belgium. In the dairy specialized regions of Upper Belgium, the Herve country and Upper Ardenne, rotational grazing is more strictly applied, and the number of paddocks is higher, from 10 to 15 in average. Three-days grazing periods per paddock and per grazing cycle are typical in this case. Two or three paddocks are usually devoted to heifers.

In beef systems, the organisation of grazing is more complex because of the existence of several herds of suckling cows and their calves grazing in separate groups of paddocks. It is not rare to observe three to five suckling cow groups grazing in separated grazing circuits. Each group, including the group of tall heifers, is accompanied by a bull. In the Ardenne, rotational grazing is usually adopted. Each group grazes in a small number of paddocks (4 to 6) during 10 to 20 days in each grazing period. Cows can be moved from one group to another for several reasons, for instance when their calves are weaned.

In dairy systems, there is also an evolution towards continuous (*ad libitum*) access of dairy cows to maize and/or grass silage during the grazing season. Since the dairy performance of cows is continuously increasing over time, farmers start to lose confidence in the potential of grasslands to feed high-yielding dairy cows properly. During unfavourable weather periods, rainy and cold or sunny and warm, farmers do not want to take the risk of an intake decrease that could led to a decline of dairy production. They start to provide silage to this kind of animals. Moreover, farmers tend to use more maize silage at the expense of grass grazing and grass silage when dairy cow production is above a certain threshold (roughly above 6,000 l/cow). Progressively, the access to silage is not restricted anymore in many cases. This trend is reinforced by the adoption of milking robot. Since cows come back several times a day to the robot for milking, the grazing area that can be really grazed can be very much reduced. It is limited by the distance to the robot. Cows may thus need to be supplemented by green forages continuously.

Forage conservation

Since the 1980s, round or square bale silage was very successful in grassland specialized regions. Notwithstanding its higher cost compared with clamp silage, this system was largely adopted because it is very flexible especially in regions were plots are small, the grassland surface of the farm is broken up and the climate is rainy. Big bale silage is typically produced from drier and slightly more mature grass than clamp silage. It is thus well adapted for conserving haylage for suckling cows.

Hay continues to be made in relatively small amounts (< 25% of harvested grassland forage) for providing a fibrous feed to particular classes of stock, e.g. young stock, horses and sheep. It is also produced in the framework of agro-environmental measures where species-rich grasslands and field margins must be cut late for improving the vegetation diversity, allowing reseeding of many flowering plants and wildlife breeding.

Photo 7. Silage making. Left: Cutting. Right: Wilting in windrows. Source: ILVO - Merelbeke.

Photo 8. Grass harvesting for silage. Left: Demonstration of machinery types. Right: Self-propelled forage harvester filling a wagon pulled by tractor. Source: ILVO - Merelbeke.

Photo 9. Haylage. Left: Round bale protected by a plastic film Source: ILVO - Merelbeke. Right: Belgian Blue cows eating haylage in a barn in winter Source: Wallonie Elevages.

Environmental objectives

Political response was initiated at European level by the adoption in 1992 of the regulations on the agri-environmental scheme (2078/92 and CEE 1257/99 regulations) that includes the support to organic farming, of the Nitrate Directive (Directive 91/676/CEE) in 1991 and of Natura 2000 (Bird (1979) and Habitat (1992) Directives). The agri-environmental scheme was transposed in Belgian regional laws relatively quickly in the 1990s. The Nitrate, Bird and Habitat Directives were only fully transposed in the beginning of the years 2000.

Agri-environmental programmes are designed at regional level in Belgium. The adoption of this programme and the payments that are associated are optional for farmers. They have two main objectives: reducing environmental risks associated with intensive farming on the one hand and preserving biodiversity and landscapes on the other hand. Agri-environment payments may only be made for actions above the reference level of mandatory requirements defined by codes of Good Farming Practices (GFP). Agri-environmental measures (AEM) include the support of the conversion to Organic Farming (OF) and of the maintenance of OF.

4. DISCUSSION: OPPORTUNITIES FOR THE IMPROVEMENT OF PASTURE RESOURCES

Since the 1990s, the negative **environmental impacts** of intensive grassland management became increasingly recognized. Nitrate leaching and water pollution by nitrate and phosphate were the first topics to emerge in grassland research on environment protection. The best techniques for slurry application were studied in detail. The effects of the total amount and the date of application of mineral and organic fertilizers, as well as the effect of stocking rate and supplementary feeding in grassland paddocks, on the nitrate residue in soil profiles in autumn were investigated. Nutrient balances were calculated at field and farm-gate levels. Researches on biodiversity conservation and restoration, and the integration of species-rich grasslands in efficient and profitable stockbreeding systems, followed quickly after these studies on water pollution. New researches were initiated on legumes that were a bit forgotten by grassland research in the previous 30 years. The inclusion of legumes in grassland swards was also seen as a way of increasing the diversity of swards. ‘Secondary’ or wild grass species were studied in a context of biodiversity restoration, of extensification and for better understanding the competition between grasses. In the beginning of the 21st century, greenhouse gas emissions from grassland soils, from the rumen of herbivores and from animal manure during storage and spreading became important research topics. The positive influence of green forage on the conjugated linoleic acid (CLA) and polyunsaturated fatty acids (PUFA) contents of milk and meat received a lot of attention for their positive effect on human health. However, holistic approaches developed slowly compared with the scientific effort in reductionist approaches.

Future research must still address these issues by integrating agricultural management with environmental protection. Research priorities for the future must notably be related with the four priorities defined in the ‘Health Check’ of the CAP in

2008: climate change, renewable energy, water management and biodiversity. Among these researches, energy consumption of the agricultural production, GHG emissions and biodiversity conservation and restoration should be particularly developed.

The issues of **climate change** on one hand and **energy savings and production** on the other hand are intrinsically linked. The reduction in energy use by agriculture will induce lower CO_2 emissions into the atmosphere. Future increases of fossil fuel price and the consequent increase of the nitrogen fertilizer price will be strong driving forces of change of Belgian farming systems in the next decades. Fundamental reforms of the systems are inevitable. In the future, systems will have to be less energy demanding. Fortunately, there are important possibilities to spare energy per ha or per ton of milk for instance (Haas *et al.*, 2001). Future researches should focus systematically on energy costs and GHG emissions per production system and per product for developing such energy efficient systems. A new integration of legume-based grasslands in crop rotations of arable land at the farm and/or the region levels will be necessary for restoring arable soil fertility, storing carbon in soils, using less nitrogen fertilizers, and for reducing transportation costs. Biological nitrogen fixation by legumes will be one of the pillars of these future systems for saving the huge amounts of fossil energy that the synthesis of nitrogen fertilizers requires.

Climate change predictions of the IPPC (Intergovernmental Panel on Climate Change) suggest higher mean temperatures and changes in rainfall distribution (more summer droughts and heavier winter rain) in Belgium. **Adaptation measures** should be adopted. *Dactylis glomerata* and *Festuca arundinacea* could for instance replace *Lolium* spp. in cutting and mixed-used (cutting and grazing) systems. New management systems should be designed for defining the best techniques for using *D. glomerata* in mixed-used swards since this grass cannot resist to intensive grazing. Legumes and particularly *Medicago sativa* and *Trifolium pratense* will certainly have an advantage over grasses in summer drought periods. Systems will have to change by starting grazing earlier in spring, by later grazing in autumn and by a higher silage use in summer. Nitrogen fertilization patterns will also have to be adapted. Since climate change models are predicting more brutal rainy precipitations in the future, grasslands could also be used for flood buffering and for enhancing water infiltration. This objective could be combined with wetland and biodiversity restoration. Researches could examine the optimization of these changes over time when they will progressively occur.

Climate changes could also be mitigated in grassland by carbon storage. That can be achieved by converting arable land to grassland with a better crop/livestock integration. Biomass produced by ‘energy lucerne’ could possibly contribute to biofuel production on arable land. Hedge planting and woodland strip plantation on grassland margins could also be carried out. Research should study the potential benefits of these techniques.

There are possibilities to increase the role of many of the **lesser-used grassland species** (grasses and legumes) for particular environments and for species-rich sward restoration. This particularly applies to Upper Belgium. Grassland species can be used for several environmental enhancement purposes like grassy field margins for erosion control in arable land, surface water protection (buffer zone) and water infiltration in grassland and arable land, species-rich field margins for restoring *i.a.* farmland bird and pollinator populations.

Grasslands should produce high amounts of **quality water** by favouring clean water infiltration. Nitrate residues in soil water should thus be reduced to a minimum but at the same time water infiltration should be enhanced. Trampling of grassland soils by high animal stocking rates and heavy grass harvesting machines for silage making have often degraded soil structure. That led to a reduction of water infiltration in grassland soils. Future researches should examine the ways of improving this situation.

A continuous improvement of **nutrient management** should be a target of future research for reducing production costs and pollutions.

Grassland forages are now recognized for having a beneficial effect on **animal product composition and human health**. Conjugated linoleic acid (CLA) contents in meat and dairy products can have a positive anti-carcinogenic effect while a low ratio of *n*-6 to *n*-3 polyunsaturated fatty acids (PUFA) has been associated with a low susceptibility to coronary heart disease. These findings create possibilities for further researches on grassland-based feeding systems. Grass-based bull and ox fattening systems should be studied for increasing efficiency, profitability and quality of the products. Similar researches should be conducted in dairy systems for the quality of dairy products. Grassland-based systems of tasty products should be developed in dairy, beef meat, pig and poultry productions. New livestock breeds could be introduced (e.g. Aberdeen Angus and rustic pig breeds) or created by selection in the perspective of a better use of grass and quality product diversification. New quality production systems should be developed or improved while minimizing their possible negative impacts on the environment, or for combining biodiversity restoration on one hand and the production of quality animal products on the other hand.

Future grassland and grassland-based system researches should focus on the **multiple functions** that grasslands offer to society. Forage and livestock systems should be supported by the society for the services they provide, including biodiversity conservation and landscape protection. They also offer recreational opportunities and they are contributing to the quality of live by producing healthy and tasty products. Future researches should take all these aspects into account.

Industrial livestock systems should be fundamentally reformed for many reasons: reduced animal welfare, low meat quality, negative impact on the environment and biodiversity, and dependence to fossil fuel. Future systems should notably have to release less Green House Gas (GHG) in the atmosphere, not only CO_2 but also CH_4 and N_20 and have a much better impact on biodiversity.

Agroecological systems that reduce costs and increase revenue should be urgently developed. Revenue is increased in these systems by targeting quality products, processing them whenever possible and selling them in short and local marketing chains. They are using local resources instead of commercial inputs. They replace these fossil-fuel based inputs by the ecosystem services provided by biodiversity (e.g. biological nitrogen fixation, pollination, pest control by natural enemies). They are adapted to climate change and have the potential to mitigate climate change by storing carbon in soils and vegetation. They are a credible answer for the future increase of input prices induced by fossil fuel rarity. They are also an opportunity to increase product quality that is expected by citizens.

Policy researches should examine the efficiency and the reform of existing programmes: the reinforcement of the cross-compliance principle, agro-environmental schemes, the support to organic farming, the implementation and the development of Natura 2000, the implementation of the High Nature Value (HNV) farmland programme, the quality product policy, the integration of ecosystem services provided by grasslands in the price of products or in financial supports. Agriculture and food policies should support the conversion to agroecology. Researches should thus look at the design of new policy programmes for reaching the multiple objectives of future Belgian agriculture.

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7.5 Germany

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1. Animal production: Facts about dairy farming in Germany

Milk production is one of the most important sectors of German agriculture. The milk production has 19% of the production value of German agriculture and Germany is the biggest milk producer in the EU. For a quarter of all agricultural farms in Germany milk production is the main source of income.

In the recent years dairy farming structurally changed in Germany. The number of dairy farms is continuously decreasing, while the number of dairy cows has not changed in Germany over the last years (Figure 1). So, the number of cows per farm is increasing (Thünen Institute, 2018). From 1970 to 2017 the number of farms decreased from 838,000 to 66,000 dairy farms. The average number of dairy cows per farm changed from 7.3 to 64 cows per farm.

Furthermore, the amount of produced cow milk is slightly increasing. In 2009, 29.2 Mio tonnes of cow milk were produced in Germany. In comparison, 31.3 Mio tonnes of cow milk were produced in 2017 (BMEL, 2017).

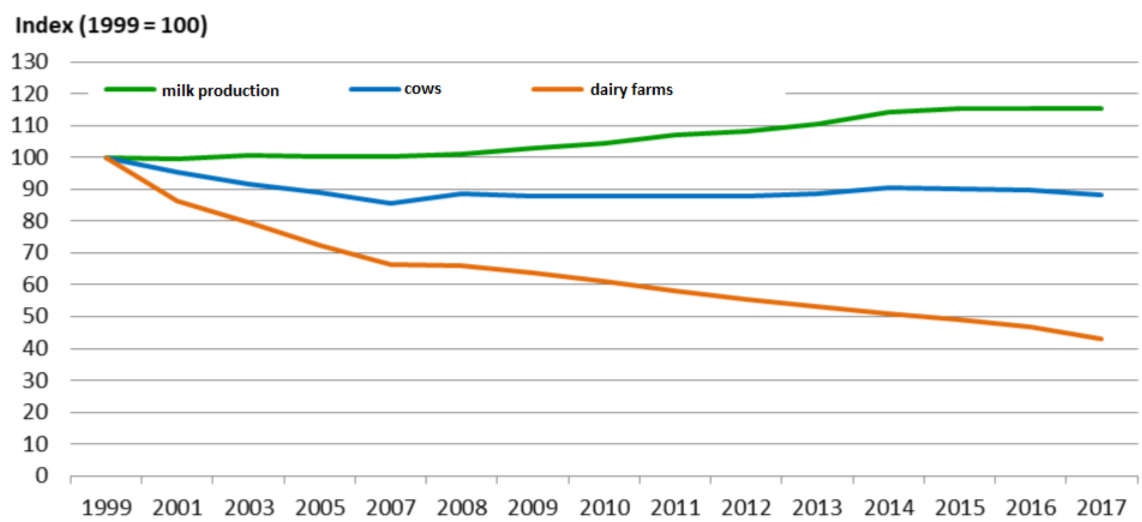

Figure 1: Development of milk production, number of cows and dairy farms from 1999 – 2017 (Thünen Institut, 2018)

Figure 2 shows that the milk production is strongly concentrated in some regions. Almost half of all dairy cows in Germany are in Bavaria and Lower Saxony. This is due to the fact that dairy farms are mainly located in grassland regions. Grassland is a valuable feed for ruminants and explains the regional distribution of milk production (Thünen Institut, 2018). From 2007 to 2015 the milk quota system has been simplified. Milk quota could be traded in bigger areas from West to East and vice versa. Previously, it was only possible to trade within smaller regions. Therefore, the milk production in north-west Germany increased since then.

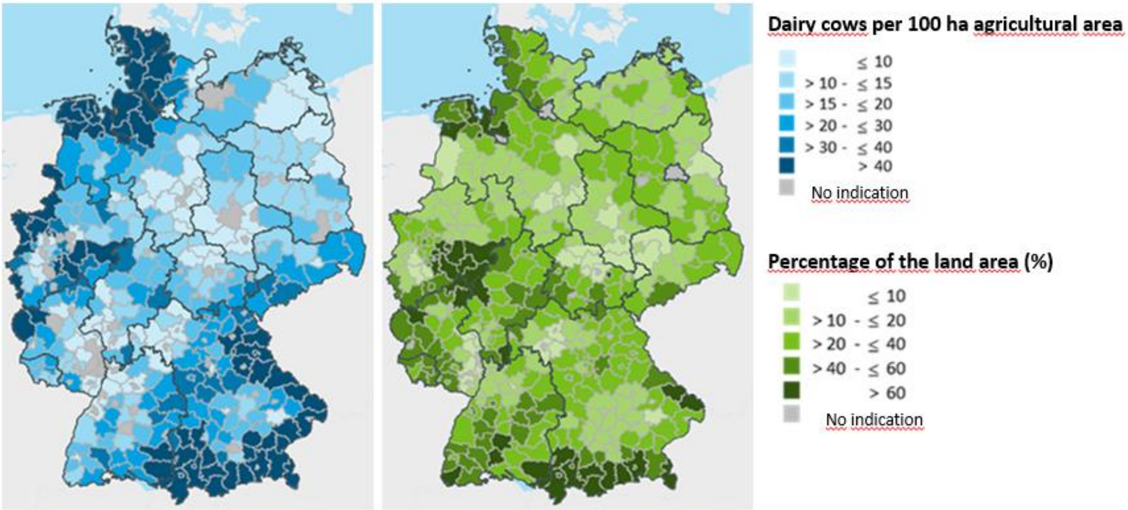

Figure 2: Relation of number of dairy cows and the percentage of grassland of area used for agriculture (Thünen Institut, 2018)

In almost all federal states the average herd size increased in the last ten years. Particularly large herds are located in eastern Germany due to historical reasons. The average herd size in eastern federal states is 188 cows. In the other federal states an average of 54 dairy cows are kept per farm. In a nationwide comparison, Bavaria has the smallest dairy farms with an average of 37 cows per farm (Table 1).

Table 1: Average herd size in Germany (own table, based on Thünen Institut, 2018)

Federal state	**average herd size (cows per farm)**
Baden-Württemberg	42
Bavaria	37
Brandenburg	226
Hesse	47
Mecklenburg-Western Pomerania	224
Lower Saxony	84
Nordrhine-Westphalia	66
Rhineland-Palatinate	59
Saarland	69
Saxony	206
Saxony-Anhalt	143
Schleswig-Holstein	93
Thuringia	175

The German dairy farming is predominately characterised by indoor systems. About 58% of dairy cows in Germany are kept in a confined system (all-year-housing) (Gurrath, 2011). The level of input differs from farm to farm. There are high, moderate and low input systems. Due to climatic conditions, farm structure and other aspects dairy cows are kept indoors for at least six months of the year. In 2010, 70 % of dairy cows were kept in modern freestall barns with bedded cubicles and a long feed table (BLE and Bundesinformationszentrum Landwirtschaft, 2019). As new buildings are in most cases freestall barns, it is assumed that the figure of 70 % of dairy cows in freestall barns even increased since 2010. An advantage of modern housing systems is the spatial separation of eating, laying and milking areas. Further it provides cows with a comfortable bed, protection from the elements and free access to a well-balanced diet. It is also possible to store and manage slurry and bedding material.

On a few dairy farms tie-stalls are still a common practice. These farms usually have smaller herds and are located in southern regions, such as the Alps. According to the Association of German Cattle Breeders (ADR), the number of tie-stall systems in Germany fell by 77 % between 1995 and 2013 (BLE and Bundesinformationszentrum Landwirtschaft, 2019).

Moreover, automatic milking systems (AMS) have become more popular on German dairy farms. In 2016, around 7,800 AMS were used on 5,500 farms in Germany. Two thirds of all dairy farmers, who decide to invest in their farm, buy a milking robot. Besides the AMS, on many farms automatic feeding systems and electronic transponder feeder systems are used (BLE and Bundesinformationszentrum Landwirtschaft, 2019)

In Germany live 4.2 Mio dairy cows, of which two-third are pure dairy breeds. Most of the dairy cows are Holstein Friesian (HF) cows (60%). In some region other breeds like Fleckvieh, brown cattle or crossbreeds are more common. They are dual purpose breeds, which are used for milk and meat production. 31 % of the dairy cows are Fleckvieh. Especially in Bavaria and Baden-Württemberg Fleckvieh is the dominant breed. In northern and eastern federal states HF in black/white and red/white are the predominant breeds (Statistisches Bundesamt, 2015; Lindena and Lassen, 2016).

Dual purpose breeds have a lower milk yield but more meat than pure breeds. The average milk yield in Germany is 7.746 kg/cow/year (BLE and Bundesinformationszentrum Landwirtschaft, 2019).

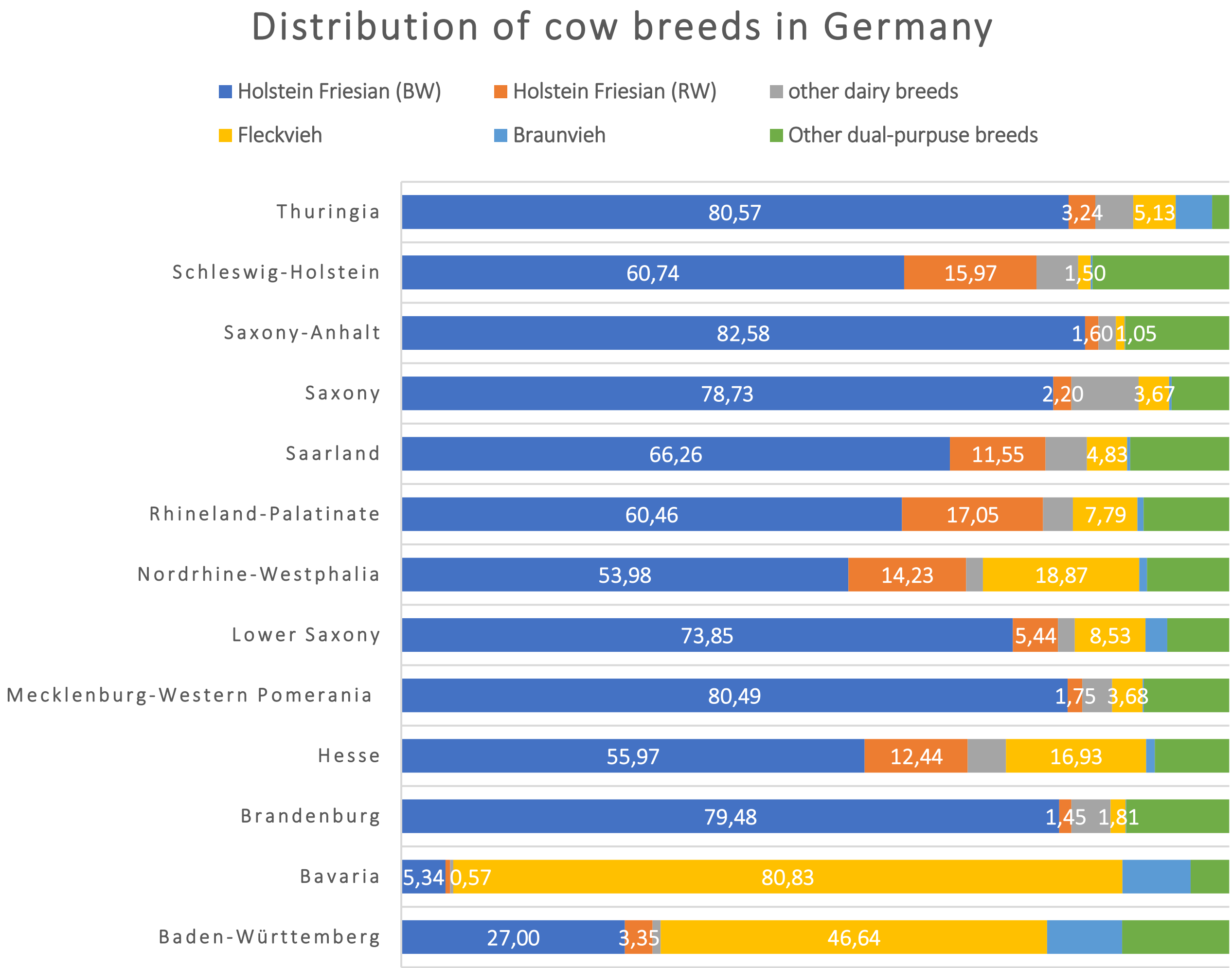

Figure 3: Distribution of cow breeds in Germany (own figure, based on Statistisches Bundesamt 2015, Land- und Forstwirtschaft, Fischerei – Viehbestand, Fachserie 3 Reihe 4.1)

2. Importance of grassland in Germany

Grassland has an important role in Germany and is characteristic for many regions. In 2017, about 4.7 million hectares were used as permanent grassland. The Grassland of the country is typically used in a meadow system (39% of permanent grassland) and 56.5% of permanent grassland is being grazed (Statistisches Bundesamt, 2019). Due to a growing demand for high-energy feed and plants for renewable energies, the proportion of permanent grassland decreased by 5% since 2003. Former grassland was converted to arable land and even sensitive sites as Natura 2000 protected areas, peatland, charted habitats and river floodplains were ploughed. The conversion causes problems for nature, climate and results in a loss of diversity (BfN, 2018).

Table 2: Permanent grassland on the type of use (Statistisches Bundesamt, 2019)

Cultures	2010	2013	2014	2015	2016	2017
	Acreage in 1000 ha					
permanent grassland	4654,7	4621	4650,7	4677,1	4694,5	4715
meadows (average use)	1899,2	1826,8	1829,6	1844	1876,8	1843,3
Grazing (including mowed pastures and mountain pastures)	2544,7	2584,6	2620,3	2651	2630,6	2664,4
low-yield permanent grassland	188	191	183,2	164,9	170	187,3
Permanent pasture (no longer in production) with entitlement to aid/premium	22,8	18,6	17,5	17,2	17,1	19,9

2.1 Silage

The main feed on German farms are fermented feeds as maize and grass silage, which is generally produced on farm land. Grass silage is predominately used as feed source on dairy farms in Germany. Grass silage is an important protein and structure feed. In recent years maize silage have become more important as an energy feed source. This is due to the fact that the milk yield per cow increased and the demands for a consistent feed quality became higher. German farmers need to focus on high-quality silage, because dairy cows are indoors for at least six months per year and calve throughout the year. This distinguishes the German system from the grass-based pasture system in New Zealand or Ireland.

Besides, concentrates are another important feed source to maintain a high milk yield and a good nutrient supply for a high-yielding cow.

Table 3: Targets for high-quality maize and grass silage (own table based on DLG, 2006)

Targets for silage quality		
	Grass silage	**Maize silage**
DM %	30 -40	28 -35
Ash % of DM	< 10	<4,5
Crude fiber % of DM	22 - 25	17 - 20
NDForg % of DM	40 - 48	35 - 40
Starch % of DM	-	>30
NEL MJ NEL/kg DM	>6,4 or >6,0	> 6,5
Crude protein g/kg DM	>135	>130

Fermentation basics of silage making

The fermentation of silage is strongly influenced by lactic acid fermentation, dry matter content (osmotic pressure), pH and the content of nitrate. In many but not all cases, the fermentation success can be explained by various biological factors such as dry-matter content, buffering capacity and sugar content. Furthermore, management factors such as silo filling speed, compacting, type of used additives, chopping length and silo management can also affect the fermentation of grass or maize. In some cases, a poor fermentation process can explain poor silage quality with a low nutritive value and a low feed intake (Kung and Shaver 2001). Therefore, German farmers take usually samples of each silage pit to evaluate the fermentation success and the feed quality. Based on the fermentation analyses the farmer determines the feeding management. In the first stage of fermentation anaerobic conditions are very important.

Anaerobic conditions

- ✓ can be created by compacting and storing the plant material under a sealed area
- ✓ oxygen - cannot be removed by compacting; it is rapidly removed by respiratory processes of the plants
- ✓ sealing prevents escaping of CO2 gas and the re-entry of air during storage
- ✓ any contact between the plant material and air initiates aerobic deterioration
- ✓ the activity of aerobic microorganism can result in decayed, inedible and sometimes toxic material
- ✓ aerobic deterioration increases dry matter losses and reduces nutritional value

Buffering capacity measures to which degree a forage sample will resist a change in pH. All forages have different buffering capacities. Fresh forage with a high buffering capacity requires more acid to reduce its pH than forage with a low buffering capacity. In general, fresh legumes have a higher buffering capacity than fresh grasses or corn (Table 4).

Table 4: Fermentability of forage (DM%: dry matter; WSC: water soluble carbohydrates; BC: buffering capacity; LA: lactic acid) (LWK Niedersachsen)

plants	DM %	WSC in g/kg DM	BC in g LA/kg DM	WSC/BC-quotient
whole crop maize (milk maturity)	**22**	**230**	**35**	**6,6**
whole crop maize (paste maturity	**30**	**110**	**32**	**3,4**
ryegrass - fresh	**20**	**173**	**52**	**3,3**
ryegrass wilted	**35**	**173**	**52**	**3,3**
other grasses - fresh	**20**	**92**	**55**	**1,7**
other grasses - wilted	**35**	**92**	**55**	**1,7**
red clover - fresh	**20**	**115**	**69**	**1,7**
red clover -	**35**	**115**	**69**	**1,7**
alfalfa - fresh	**20**	**65**	**74**	**0,9**
alfalfa - wilted	**35**	**65**	**74**	**0,9**

Buffering Capacity (BC)

- ↘ Amount of lactic acid which is necessary to drop down pH value of < 4,0
- ↘ Resistance of plant material adverse pH-shift
- ↘ Raw protein, minerals and soil materials have buffering properties

Extremely wet silages (< 25% DM), prolonged fermentations (due to high buffering capacity), loose packing or slow silo filling can result in silages with high concentrations of acetic acid (> 3 to 4% of DM). In such silages, energy and DM recovery are probably not ideal. Silages treated with ammonia also tend to have higher concentrations of acetic acid than untreated silage, because the fermentation is prolonged by the addition of the ammonia which raises the pH (Kung and Shaver 2001).

High concentrations of ammonia (>12 to 15 % of CP) are result of excessive protein breakdown in the silo caused by a slow drop in pH or clostridial action. In general, wet silages have higher concentrations of ammonia. Extremely wet silages (< 30 % DM) have even higher ammonia concentrations, because of the potential for clostridial fermentation. Silages packed too loosely and filled too slowly also tend to have high ammonia concentrations (Kung and Shaver 2001).

Grass types

Perennial ryegrass is the most common grass type used on German grassland for silage production. Due to high yield potential and good feed quality it is characterized by a relative high amount of water soluble carbohydrates (WSC, sugar) compared to other grass types (Table 5, LWK).

Table 5: Types of grasses and the fermentability (DM%: dry matter; WSC: water soluble carbohydrates; BC: buffering capacity; LA: lactic acid) (LWK Niedersachsen)

grass types	DM in %	WSC in g/kg DM	BC in g LA/kg DM	WSC/BC-Quotient
italian ryegrass, WV	20,0	190,0	55	3,5
perennial ryegrass; WD	21,0	155,0	44	3,5
timothy; WLG	22,0	75,0	40	1,9
orchard grass; KG	22,0	95,0	43	2,2
meadow fescue; WSC	23,0	90,0	55	1,6
bluegrass, WRP	19,0	80,0	53	1,5

Further, the right cutting date has a stronginfluence on the feed quality. Figure 4 shows the varying energy content (NEL) of different grass types at different development stages.

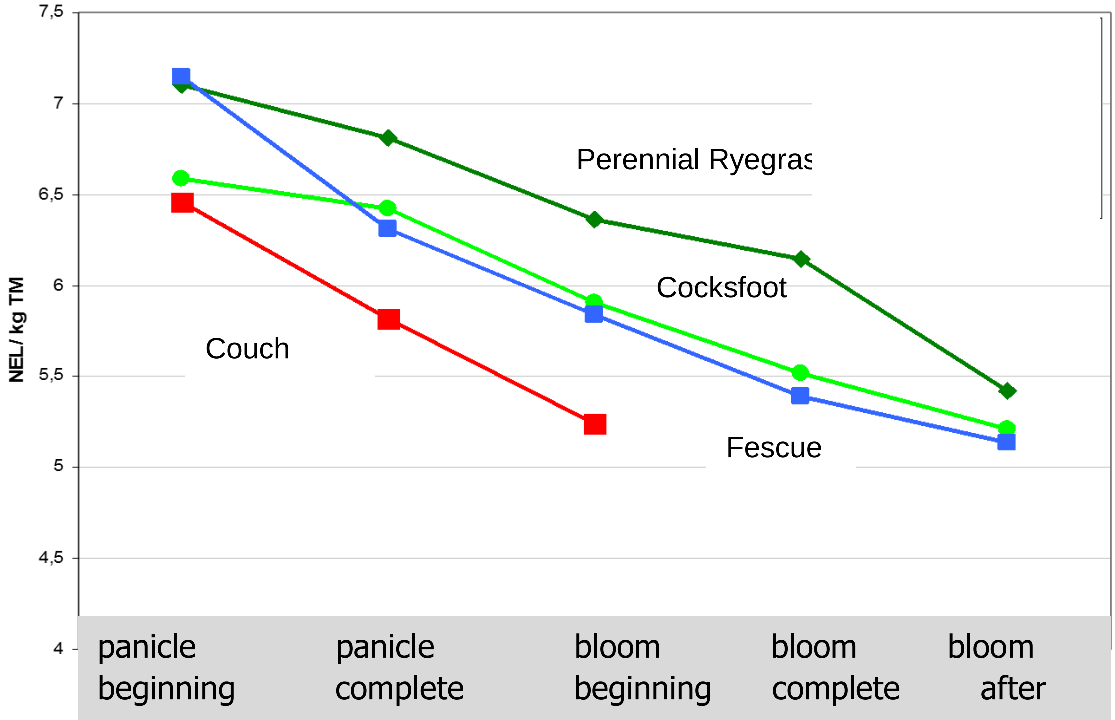

Figure 4: Relation between the energy content (NEL) and the development stages of different grass types (LWK Niedersachsen)

2.2 Grazing

Grazing is still a common practice on many German dairy farms during the summer months. About 42 %of the dairy cows graze on average for five months per year (BLE, 2019). Regarding to this, having access to pasture and an active uptake of fresh grass is perceived differently. Some farms concentrate on the advantages concerning cows health, animal comfort, environmental and economical aspects, while others include fresh grass as an important component of their cows diet.

However, there are limiting factors to give access to pasture in some regions (Pries, 2004). Due to structural changes on German dairy farms, it seems to be difficult to provide enough grazing area for larger herds with more than 200 cows. Too small paddocks and long distances between paddock and milking parlour limit the grazing time and feed intake per cow from fresh grass. Medium-sized farms offer more time on pasture than farms with large herds. Every second cow at medium-sized farms (50 to 200 cows) has access to pasture (Figure 5).

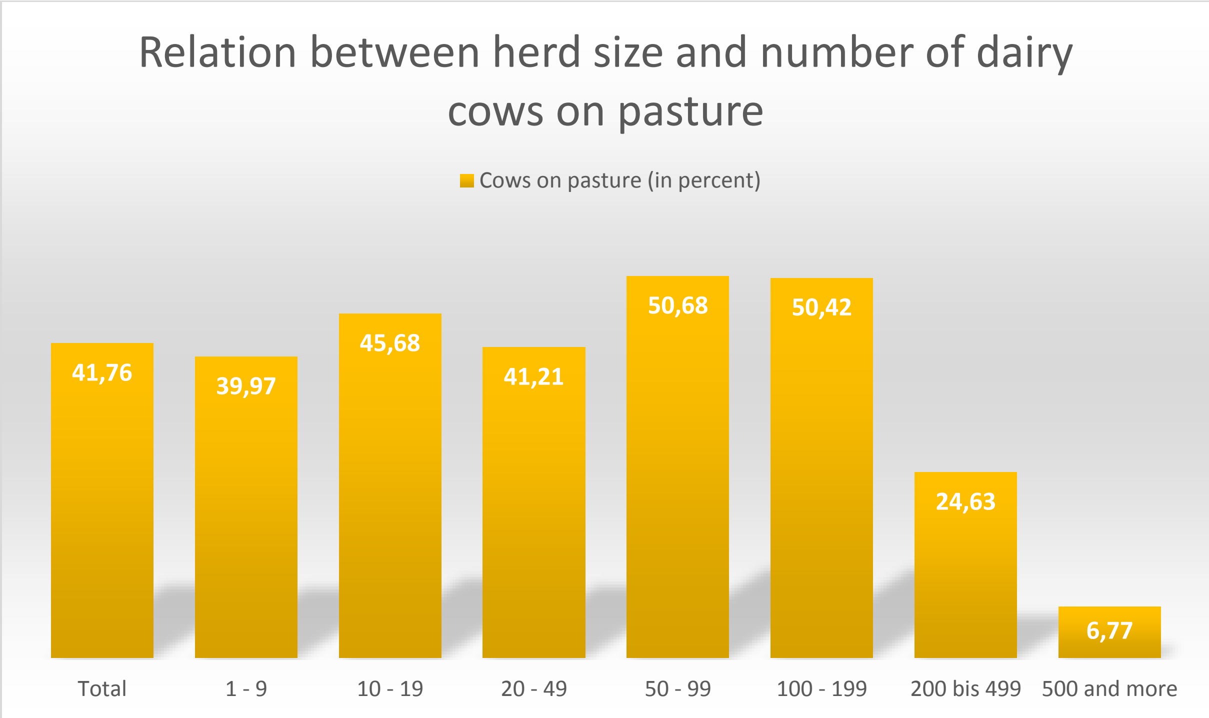

Figure 5: Relation between herd size and number of dairy cows on pasture in Germany (own figure based on Destatis, 2010)

In German grassland regions it is more common to give cows access to pasture. In the federal states North Rhine-Westphalia, Schleswig Holstein and Lower Saxony more than 50% of the dairy cows have access to pasture (Figure 6).

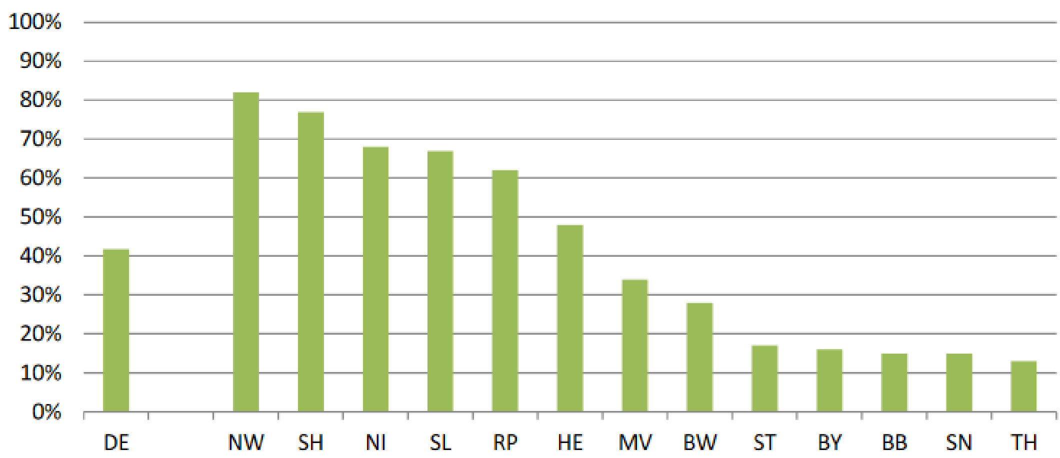

Figure 6: Percentage of grazing in the federal states of Germany (Thünen Institut, 2018)

In Germany different grazing systems are in practice. The overall aim of the different grazing systems is to obtain as much milk as possible directly from grass. Further it is important to ensure a constant feed quality and minimal feed losses. The choice of the grazing system is independent of the actual grazing time.

Kurzrasenweide/short grass system (Steinberger, 2011; Steinberger, 2017)

- allocation of the entire paddock
- pre-grazing height 5 to 6 cm
- residual height 4 to 3.5 cm
- frequent bites limits the dry matter absorption
- high quality feed, high digestibility
- good palatability of the grass
- little feed losses
- more milk per ha
- dense sward due to short rotation length

Rotational grazing (Grünlandzentrum, 2018)

- pre-grazing height 11 to 8 cm, graze swards at 3-leaf stage
- post-grazing height 4 to 3,5 cm
- pre-grazing height depends on growth rate
- high DM-yield
- grass offer is adapted to cow´s demand
- removeable fences offer access to only a part of the paddock
- 2 to 4 grazings/paddock
- longer resting time than grazing time

Continuous grazing (Grünlandzentrum, 2018)

- allocation of a pasture block
- block size at least 4 ha
- graze block for 3 to 6 weeks
- labour-saving

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7.6 Poland

Piotr Goliński and Barbara Golińska (Department of Grassland and Natural Landscape Sciences, Poznan University of Life Sciences)

Grassland status

Poland is a country with varied topographic, climatic and edaphic conditions. This diversity has multiple consequences manifested primarily in land use. Permanent grasslands occupy in Poland the total area of 3.2 million hectares (Table 1), which constitutes 21.7% of the total utilized agricultural area or 10% of the entire land of the country. The above-mentioned area comprises natural, semi-natural (i.e. periodically subjected to renovation) and agriculturally improved permanent grasslands (renovated, fertilized and intensively utilized for forage production). In regions with a limited area of permanent grasslands and a predominance of arable land, temporary grasslands play an important role in the production of bulky fodder. Grass-legume mixtures are particularly important among plants cultivated on such grasslands because their production potential and high nutritional value ensure that the feeding requirements of high-production ruminants are met. Nowadays, leys established on arable land covering about 0.4 million ha, whose time of utilisation does not exceed 4-5 years (Table 1).

Table 1. Changes in the utilized agricultural area (UAA) in Poland (million ha) (GUS, 2018)

Item	1990	2000	2005	2010	2017
Arable land of which	14.388	13.940	12.220	10.428	10.757
Temporary grasslands	n/a	n/a	n/a	n/a	0.414
Permanent meadows	2.475	2.503	2.528	2.629	2.796
Permanent pastures	1.585	1.369	0.859	0.654	0.375

In recent decades, the proportion of permanent grassland in Poland has decreased from 4.06 (1990) to 3.17 (2017) million ha (Table 2). In comparison with the state of grasslands in 1990, the share of permanent meadows in UAA increased by ca. 40% but the percentage of permanent pastures in UAA has fallen by almost 70%. In 2017 meadows make up 88% and pastures 12%.

Table 2. Changes in the area and structure of permanent grassland in Poland (GUS, 2018)

Permanent grassland	1990	2000	2005	2010	2017
Area (million ha)	4.06	3.87	3.39	3.28	3.17
Percentage of UAA including:	22.0	21.7	21.3	21.8	21.7
Meadows	13.4	14.1	15.9	17.4	19.1
Pastures	8.6	7.6	5.4	4.4	2.6

The distribution of grasslands in Poland varies with their higher proportion in the structure of UAA in North-Eastern Poland as well in South-Eastern part of the country (Figure 1). Majority of grasslands are situated in river valleys and mid-field depressions as well as in foothill and mountain areas, which are impossible for the cultivation of ordinary crop plants. Water is the main factor determining the properties of grassland habitats and phytocenoses in Poland (Grzyb and Prończuk, 1995). Achieving sufficient humidity of grassland habitats depends on adequate water management, particularly with regard to maintaining the operational water and drainage facilities and restoring dysfunctional systems. Action is often required to ensure the collection of any amount of water (small water retention) with it being important to retain water from the catchments of particular rivers in early spring (Nyc and Pokładek, 2008).

Figure 1. Location of permanent grassland in Poland based on remote sensing (Dąbrowska-Zielińska *et al.* 2015)

The characteristic of Poland's surface features causes that 90% of grasslands are taken up by lowland meadows. They comprise: dry-ground meadows, flooded meadows, boggy meadows and post-boggy meadows. Boggy meadows occur in wet habitats and they are not important for fodder production, but they play an important environmental role. The other types of meadows are used for fodder production. However, insufficient soil humidity levels, resulting from small amounts of precipitation, lead to decreased persistence and productivity of these meadows, particularly in dry-ground habitats. Insufficient humidity levels in post-boggy meadows lead to the degradation of peat-muck soils occurring there and, in consequence, to unfavourable changes in the floristic composition of these phytocenoses. The optimum environmental and economic effects in valley grasslands (particularly located on organogenic soils) can be achieved by using surface irrigation and upward-irrigation systems (Nyc and Pokładek, 2008). Thus effective water management in a habitat is the basic condition required to enable further measures aimed at improving the production from permanent grasslands through fertilisation, management and technology.

Most of Polish permanent grasslands have been characterised by great biological diversity (Warda and Kozłowski, 2012). This results from the influence of favourable natural conditions (location in a central part of the continent, in a transitional climate zone, lack of natural barriers in the east and west, varied geological structure and diverse landforms) as well as from the peculiar impact of human activity, different than in other European countries (uneven degree of industrialisation and urbanisation, low-input farming with a moderate level of fertilisation and land use, as well as extensive and historically permanent forests).

Biodiversity may be very high in permanent meadows. More than 700 species of vascular plants and their presence in 100 different botanical families has been found in grassland communities (Kozłowski and Stypiński, 1997). Some of them are very rare in Europe and they are protected by law. Polish meadows are characterised by the floristic diversity of their sward, which distinguishes them from meadows in other countries, particularly in Western Europe. The main factors determining the floristic diversity of a grassland sward are the properties of grassland habitat and the intensity of farming practice and utilisation. More sward species are also recorded in the plant communities of permanent grasslands occurring on mineral soils than on organic soils (Baryła, 2001).

A proper analysis of the floristic diversity of meadow communities must take into account their syntaxonomy. The floristic diversity of the same associations and communities may vary across different regions of Poland (Kucharski, 1999). Communities in very wet habitats (the *Phragmitetea* class) are characterised by a smaller species diversity resulting from a small number of dominant species (Kryszak and Grynia, 2005). A much greater floristic diversity characterises the phytocenoses of moderately wet and periodically dry habitats of the *Molinio-Arrhenatheretea* class (Warda and Stamirowska-Krzaczek, 2010).

Grazing livestock and their relation to grassland

There is a close relationship between the status of permanent grassland use and the number of livestock for which meadow and pasture swards constitute feed base. The grazing livestock in Poland reached the peak numbers between 1975 and 1989. The maximum cattle population of 10733 thousand heads was noticed in 1978 and sheep – 4991 thousand heads in 1986. Just after the political regime changes in 1989, the maxima were followed by slow declines until 1990-1991. Between 1991 and 2002, numbers of cattle and sheep dropped sharply to 5533 and 343 thousand heads, respectively. After this period, they decreased relatively slowly until 2007. From 2008 the cattle population is growing slowly and sheep numbers still decreased. According to newest statistical data (GUS, 2018) the cattle numbers in 2017 reached the share of 61.1% and sheep only 5.7% of the population in 1990 (Table 3). The numbers of horses between 1990 and 2017 also dropped to ca. 20% of the 1990 state.

Table 3. Changes in the number of grazing livestock (thousand heads) in Poland (GUS, 2018)

Farm animals	1990	2000	2005	2010	2017
Cattle	10049	6083	5483	5742	6143
of which dairy cows	4919	3098	2755	2529	2153
Sheep	4159	345	316	261	239
Horses	941	550	312	264	185

The differentiation of share of permanent grassland in UAA in specific voivodships of Poland is related with cattle stock per 100 ha of UAA. As shown in Figure 2 the highest cattle stock in heads per 100 ha of UAA in 2017 occurred in Podlaskie voivodship. The low density of cattle and sheep in Southern part of Poland in condition of high share of permanent grassland in UAA, resulted in their abandonment and affected the process of their natural afforestation leading to losses of open landscapes in this region.
Milk production in Poland in 2017 reached the level of 13310 million kg (Table 4) and, in comparison with 1991-1995, it was by over 2000 million kg lower. In the same period of time, the annual milk yield per cow increased from 3083 kg to 5687 kg. In the herds under milk recording, which includes ca 37% of total dairy cows, the annual milk yield per cow reached the level of 7771 kg.
One of the leading milk production regions in Poland is Podlaskie voivodship situated in North-Eastern part of the country. There are 2500 dairy farm above 50 heads in that region and they produce 22% of milk purchased in Poland and 90% of this amount fulfils EU standards. The stocking rate of dairy cows per 100 ha agricultural land in that region in 2018 was 41.6 LU, while the average stocking rate of dairy cows in Poland was 15.3 LU (GUS, 2018). For this reason, the North-Eastern part of Poland can be described as the region specializing in milk production based on grassland, where their management focusing on sustainable intensification plays an important role.

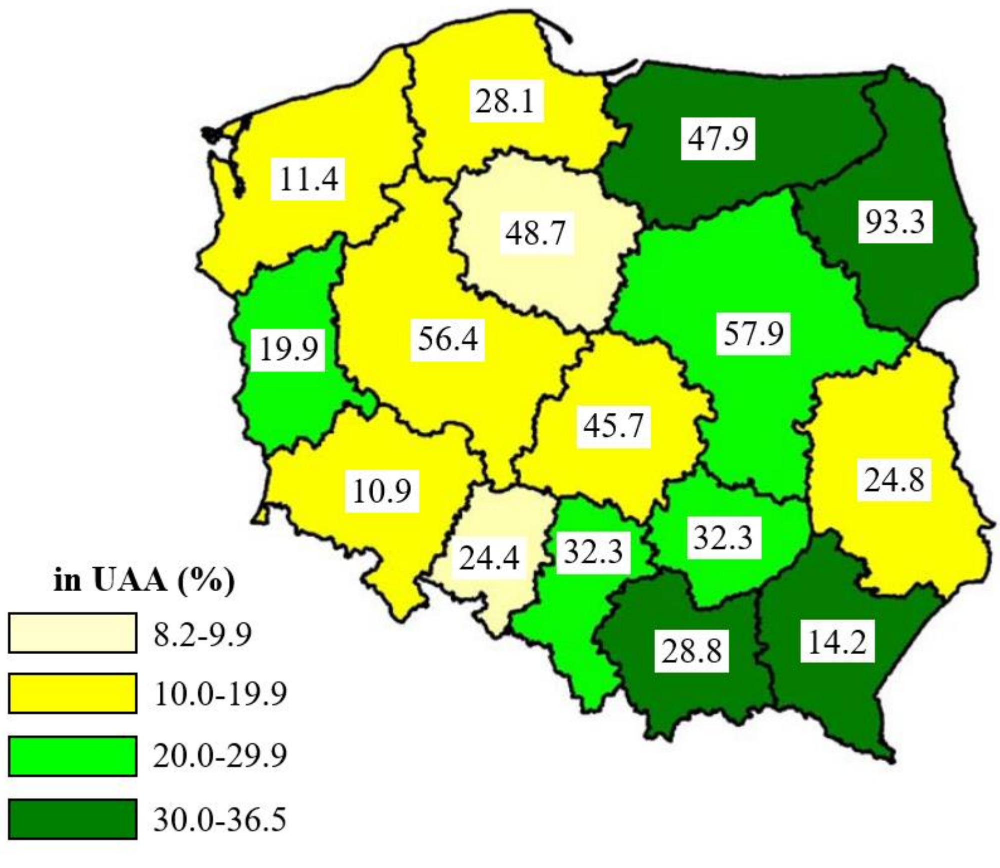

Figure 2. Share of permanent grassland in UAA and cattle stock in heads per 100 ha of UAA by specific voivodship (own elaboration based on GUS, 2018)

Table 4. Changes in the milk production and yield in Poland (GUS, 2018)

Item	1991-95	2000	2005	2010	2017
Milk production (bn kg)	15.40	11.49	11.58	11.92	13.31
Average annual quantity of milk per cow (kg)	3083	3828	4147	4487	5687
under milk recording (kg)	4209	5379	6508	6980	7771

Apart from Podlaskie voivodship also Mazowieckie and Wielkopolskie are the leading regions in milk production in Poland. They produce 22% and 15%, respectively, of milk purchased in the country. It is worth to emphasizing that in Mozawieckie like in Podlaskie the feeding of dairy cows is based on feeds from temporary and permanent grasslands, while in Wielkopolskie the fodder dose is composing mainly of maize silage.

Nowadays, there are three models of milk production in Poland in terms of the fodder use from grasslands:

- intensive milk production using TMR/PMR system with important role of silage/haylage from permanent/temporary grasslands (milk yield 10000-12000 kg per cow), HF breed;
- low-cost technology of milk production with very important role of pasture and/or silage/haylage from permanent/temporary grasslands (milk yield 7000-8000 kg per cow), HF breed and/or dairy cattle breeds adapted to grazing;
- pro-ecological/ecological milk production with crucial role of pasture and/or hay from permanent/temporary grasslands – feeding without silage (milk yield 5000-7000 kg per cow), dairy cattle breeds adapted to grazing.

From the point of view of market output which results from the transfer of fodder derived from grasslands, grazing livestock meat and wool are also important. In the beef production a dramatic decline was observed when comparing years 1991-1995 and 2005 (Table 5). Since this year a significant increase of beef production with promising development of beef export in last period is observed. Wool production dropped from 5386 tons in years 1991-95 to the level of 620 tons in 2010. In the last year a slowly increase is noticed.

Table 5. Changes in the beef and wool production in Poland (GUS, 2018)

Item	1991-95	2000	2005	2010	2017
Beef production in post-slaughter warm weight (thousand t)	652	321	313	389	563
Wool production – sheep's greasy (t)	5386	1322	998	620	774

Grassland productivity and management

Permanent grasslands dominate (76.1%) in the structure of fodder area in Poland (Figure 3). In the analysis, including forage production from main crops, maize cultivation occupies a share of 13.1% and temporary grassland (grass and grass-legume mixtures, as grasses and legumes in pure stand growing for feeds) 10.8%.

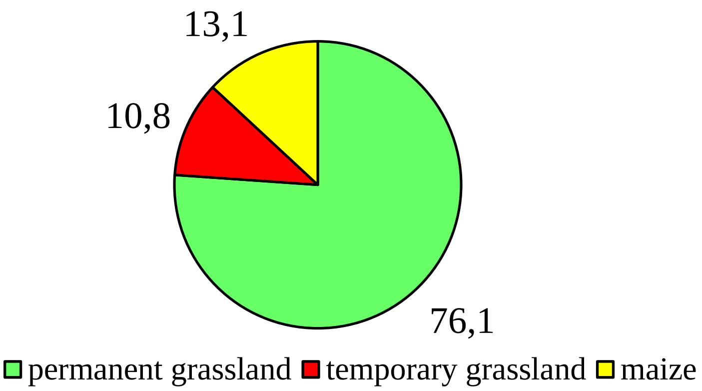

Figure 3. Structure of fodder area in Poland (own elaboration based on GUS, 2018)

Because of low productivity of permanent grassland in Poland the feed base for ruminants, particularly for dairy cows, is secured by wilted silage from temporary grasslands and maize silage. As reported by Zastawny (2000), the fodder low quality from permanent grasslands before 2000 was confirmed by the fact that they occupied 69.9% of the total fodder area in Poland, whereas 30.1% of the area occurred in the form of fodder crops on arable land (incl. temporary grasslands). However, permanent grasslands provided only 36.0% of nutritional (oats) units production in comparison with 64.0% from fodder crops on arable land.

In 2017 the average yield of permanent grassland in Poland was 5.21 tons of hay per hectare (GUS, 2018). Taking into account the different yielding of meadows and pastures the total production of permanent grasslands in this year, calculating into hay as air-dry matter, was 15.15 thousand tons from meadows and 1.37 thousand t from pastures. Although the statistical data show o low productivity of grassland, the investigation results regarding determination of DM and crude protein yields carried out on good managed productive grassland, particularly in dairy farms, prove that there are a huge forage resources in Polish grasslands. A good example is the synthesis of mutliyear PULS research conducted mainly in Wielkopolska region, where weather conditions due to frequent shortages of precipitation negatively affect the productivity of grassland (Figure 4).

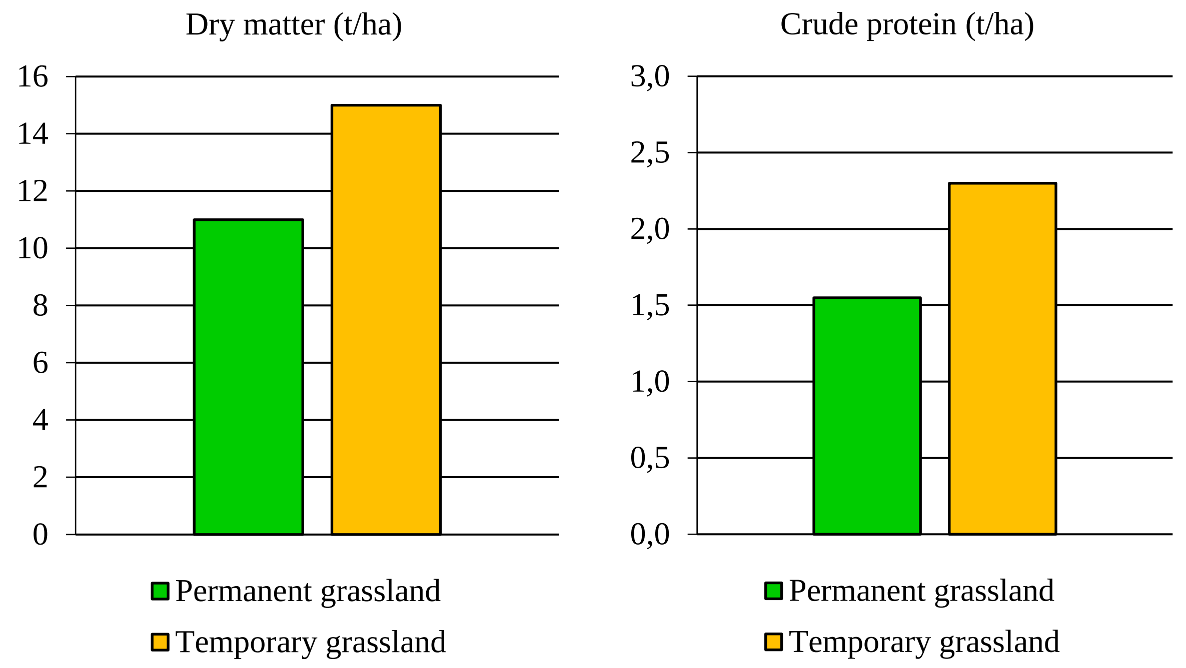

Figure 4. Potential yields from grassland in Poland (own elaboration based on synthesis of mutliyear PULS research)

The majority of Polish grasslands is utilised by cutting. The pasturing of dairy cattle has decreased not because of the low effectiveness of this feeding method, but in order to limit the involvement of the labour force, particularly in farms with a small number of staff (Wasilewski, 2011). The sward conservation is predominated in the form of hay. Production of hay from the first cut is on average 60% and from the second ca. 50%. The remaining amount of sward is ensiled, mainly in form of wilted silage containing 30-40% of DM. Comparing various regions, the largest amount of silage from meadow swards (30%) is produced in the Podlaskie voivodship (Jankowska-Huflejt and Domański, 2008). Only very few harvested sward from grassland (less than 3%) is conserved as dried fodder in drying plant.

The input of NPK (nitrogen, phosphorus, potassium) in the period 2015-2016 was at the level of 130.3 kg ha^{-1} of agricultural land, of which nitrogen takes 71.7 kg ha^{-1}, phosphorus – 22.4 kg ha^{-1} and potassium – 36.2 kg ha^{-1} (GUS, 2018). It is estimated that the annual input of nutrients in fertilizers on grasslands is smaller and does not exceed, in the case of nitrogen, on average 50 kg ha^{-1}.

After Poland's accession to the EU on May, 1st 2004, the situation of Polish agriculture changed considerably. The following aspects deserve mention when grassland management is taken under consideration:

- direct subsidies calculated per 1 ha. They will be paid on the condition that grasslands are utilised – at least one-time cutting or grazing;
- financing of programs connected with the protection of natural environment and rural landscape. The financial resources are intended for funding various measures in high-nature value areas, which, from the point of view of EU, possess special significance for natural protection and which form part of the Natura 2000 program. The European Commission has already approved 849 "habitat areas" and 114 "bird areas" in Poland, accounting for about 20% of the

territory of Poland. The above-mentioned activities include, among others, maintenance of extensive meadows (one-time and two-time cuttings) as well as extensive pastures (xerothermic plant communities, mountain pastures) and on which renovation – both resowing and complementary seeding – is banned;

- subsidies intended for milk production modernization, for instance, purchase of machines for the production-, harvesting-, and conservation of feed, pasture establishment and renovation etc., as well as restructuring of farms specializing in beef cattle and sheep;
- individual milk quotas (abolished in 2015).

Some of the above elements, especially those referring to milk production, are intended to stimulate renovation of grasslands and ley farming. The more so, since after Poland's accession to the EU, the economy of cereal production decreased.
The pattern of land use reflects the size and structure of farms. More than 95% of farms are individually- and family-owned. There are ca. 1400 thousand farms in Poland with the average farm size of 10.8 ha in 2018 (GUS, 2018). In last years, the structure of agricultural farms was slowly changing. Their average area grew through the purchase or lease of land, which enhanced their competitiveness and economic efficiency. However, regional differences in the structure of farms remain. South-Eastern Poland is characterised by a large number of small farms, while farms with the largest tracts of land can be found in Northern Poland. Farms over 15 ha in size managed in 2017 on 60.6% of agricultural land, although they constitute only 15.2% of the total number of farms. There are 342101 farms maintaining cattle of which 270831 – dairy cows in 2016 (GUS, 2018). For this reporting year only 9426 farms are keeping sheep and 9791 – goats. The number of horse farms was at the level of 61229. There are only 11395 farms in which the share of revenues from sales of products and services from economic activity other than agriculture directly related to the farm in total sales of farm production is more than 50%.

Grassland renovation and establishment of new grass sward

The main causes of the process of grassland degradation in Poland include:

- unfavorable site changes caused either by excess or deficit of water during the vegetation season (e.g. drought in 2018);
- overwintering conditions unfavorable for fodder grass and legume species (the disappearance of *Lolium* sp. coincides most often with freezing of winter barley and rape);
- negligence on the part of farmers in the area of grassland management, especially concerning fertilization and utilization.

Re-sowing involving the destruction of the old sward and sowing of a new mixture is recommended in situations of a strong degradation of grasslands which includes:

- very small presence in the sward of valuable grasses and legumes;
- high proportion in the sward (over 40% in coverage) of undesirable and troublesome rhizomatous (*Cirsium sp.*, *Rumex sp.*), toxic (*Ranunculus sp.*), hydrophilic (mainly *Juncus sp.*, tussock-forming *Carex sp.*) weeds and mosses;
- over 20% share in the sward of *Deschampsia caespitose*;
- soil impoverishment, its destroyed structure with content of acid humus;
- considerable sward destruction by moles, rodents and wild boars.

In the consecutive years, following the intensifying process of meadow degradation, the applied renovation treatments should include complementary seeding and, if

production cost of 1 MJ energy continued to increase, the old sward should be destroyed and new grass-legume mixture sown. It is worth emphasizing that complementary seeding should be applied appropriately early.
At the present time, decisions concerning grassland renovations are taken exclusively on the economical basis and depend on the demand for high quality feed for ruminants. In fact, it refers mainly to farms specialising in dairy cattle production (Figure 5).

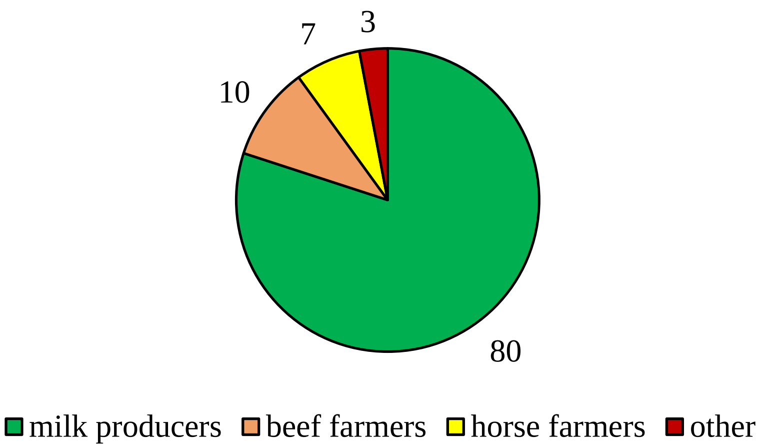

Figure 5. Structure of the use of biological progress in grass and legumes breeding by type of farmers (%) (own elaboration based on Polish Seed Chamber data)

On the basis of information obtained from the Polish Seed Chamber about the quantities and structure of sold seeds of grasses and legumes it can be estimated that in the last three years seed mixtures were sown on the area of 120 thousand ha annually. Most of these mixtures were used to establishment of temporary grassland. Grasslands on farms specializing in milk production are renovated systematically every 5-6 years. As expected, the operation is carried out more frequently if it is warranted by the appearance of factors resulting in their degradation (Goliński, 2007). The feed base is frequently supplemented by sowing grass-legume and grass mixtures on arable land and their cultivation is competitive for maize. Due to the specificity of site conditions, temporary grasslands are established more frequently in Northern and Eastern Poland than in the Central and Western parts of the country where maize cultivation is preferred. The trend to increase acreage under maize in dairy farms observed in recent years has been strengthened by the marketing of new maize cultivars, which are better adjusted to regions with shorter vegetation periods or in years with drought period resulting in yield drops from grasslands.
There is a rich marketing offer of grass and legume seeds in Poland at the moment but the mixtures of these seeds are characterised by considerable diversity even though they appear to be intended for the same purpose. In addition, there are also frequent mistakes both with regard to the species composition and quantities of individual components to be sown. That is why, the Polish Seed Chamber introduced on the Polish market in 2004 standard mixtures intended for grasslands (Goliński *et al*., 2003). Their application by seed companies is not compulsory but should be treated only as recommendation.
For complementary seeding of permanent grasslands the most suitable grass species is perennial ryegrass. The meadow fescue is taken into consideration on

organic soils. An option for permanent grassland renovation using oversowing or overdrilling by some dairy farmers are hybrid ryegrass, Italian ryegrass, westerwold ryegrass and festulolium. They are applying such species with awareness that they are temporary and the permanent grassland need to be systematically improved each two years. From among of legumes most suitable for complementary seeding are white clover on pastures, red clover on meadows located on mineral soils and alsike clover on meadows located on organic soils. In very few cases a bird's-foot trefoil and alfalfa are applied. It is important to select varieties preferred for complementary seeding, which are distinguished by the ability to quickly rooting – installation in old sward and a high competitiveness.

Regarding to suitability of grasses and legumes for mixtures using in total sod renovation of permanent grasslands, the ranking of the importance of grass species (from most to less important) are perennial ryegrass, meadow fescue, tall fescue, timothy, smooth-stalked meadow grass, cocksfoot, red fescue, black bent, tall oat-grass, and others. The ranking of the importance of the legume species for mixtures (from most to less important) is as follow: white clover (particularly small-leaved varieties), alsike clover, red clover and bird's-foot trefoil.

In the set-up of temporary grasslands are suitable the most productive grass and legume species. From grasses the most important species for pure sowing or mixtures (from most to less important) are Italian ryegrass, westerwold ryegrass, perennial ryegrass (mainly tetraploid varieties), festulolium, meadow fescue, timothy, tall fescue, cocksfoot and brome grass. The importance ranking of legume species is as follow: alfalfa, red clover, white (large-leaved varieties), alsike clover, crimson clover, Persian clover, bird's-foot trefoil, Egyptian clover and common sainfoin.

The outcome of the process of grassland renovation resulting from the improvement of the botanical composition of its sward should include both the increase of yields and herbage quality and the two elements can occur jointly or separately. The resultant increase of yields or quality improvement of forage should fully recompense the costs incurred by the renovation. Numerous economic analyses indicate that the improvement of herbage quality from grasslands after renovation is justified by milk production. Goliński (1998) maintains that in view of the progressing degradation of meadows and pastures, the ratio of the production costs of 1 kg DM, 1 MJ energy and 1 kg protein of feed to the upgrading value of feed in animal production is very important. A rational indicator of the moment to perform meadow oversowing or overdrilling is when the value of the ratio of the production cost of 1 MJ feed energy to the upgrading value of feed in dairy cows production reaches 1.2-1.5. A later application of complementary seeding can be justified on condition that the old sward are increasingly damaged (mechanically or chemically) and amounts of seeds for oversowing or overdrilling keep increasing. On the other hand, further grassland degradation associated with increasing ratio of the production cost of 1 MJ energy to the upgrading value of feed requires the type of renovation involving the re-sowing.

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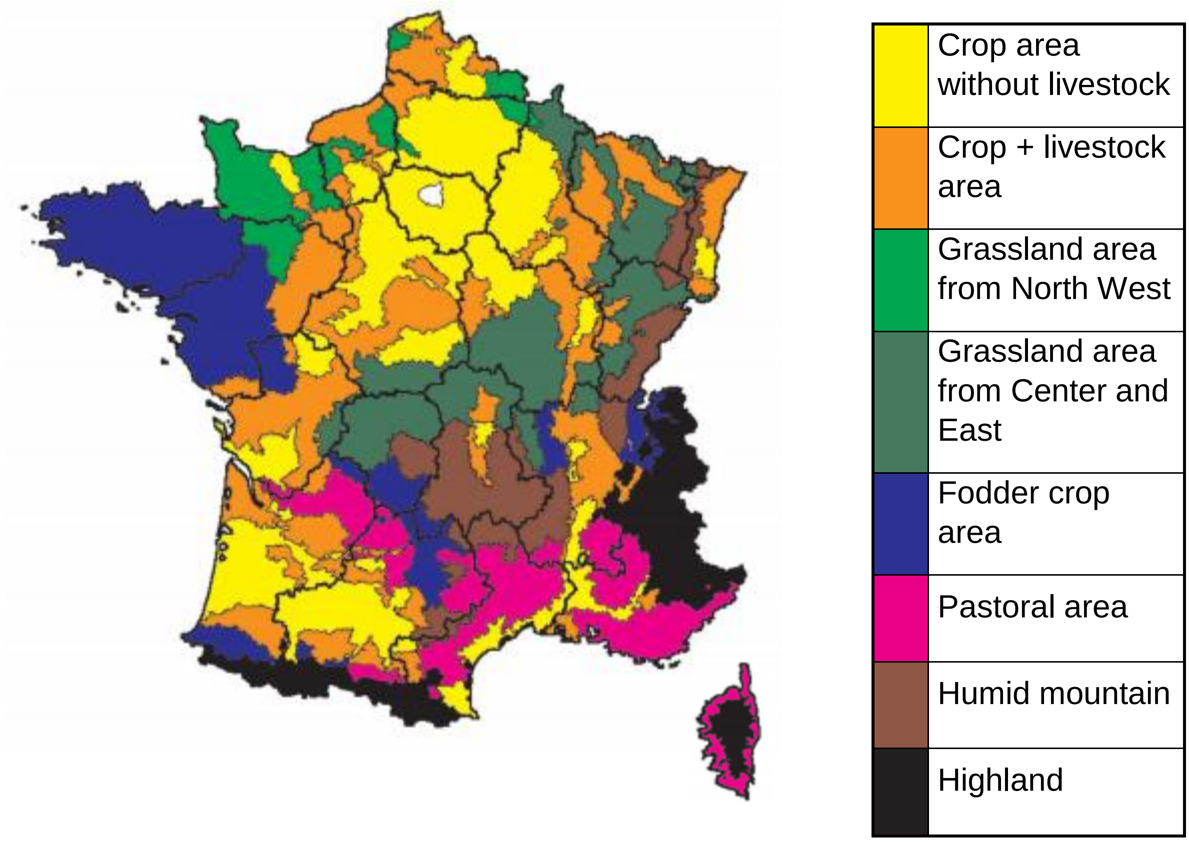
7.7 France

Julien Fradin (IDELE)

<u>Introduction</u>

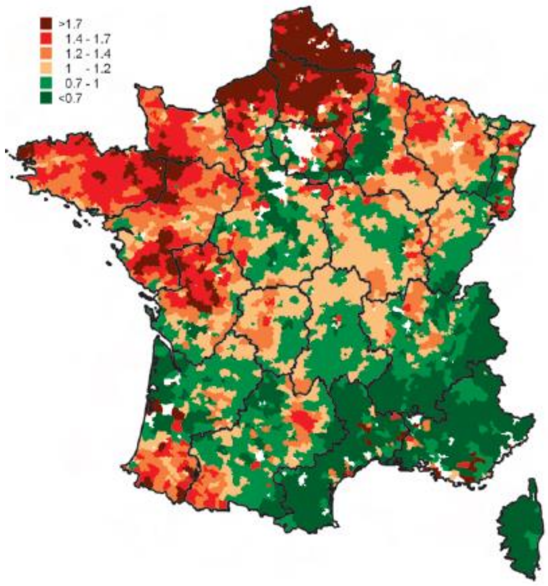
The French useful agricultural area is 27 million ha, including 12 million ha of grain crops and 11 million ha of grassland, there is also 25 million ha of forest (BPSCA, 2018).Related to its geography, metropolitan France has many climates with varied influences (oceanic, continental, mountainous and mediterranean) combined with soils of different nature, this cocktail of pedoclimatic situation allows the expression of a diversified agriculture.

Based on the presence or absence of herbivore rearing, the dominant crop rotation of the region, soil potential and altitude, an illustration of the main regions dedicated to livestock is proposed according to 8 categories. In the first place, a dichotomy takes place between lowland areas and areas with higher altitude. In the lowland, some areas of the territory are dominated by arable crops where ruminant livestock is mostly absent. Nearby, intermediate areas often defined by a lower grain production potential, have developed integrated crops and livestock system. The intensive areas of the West and Piedmont, where maize silage plays an important role in the farming system, are dominated by dairy farming in general or suckling veal production in the western Massif Central. Grassland areas from lowlands (North West, Center and East) are characterized by a higher proportion of permanent grasslands where dairy and suckler cows coexist. Finally, the pastoral zones, located at various altitudes, are defined by a very extensive stocking rate utilizing semi-natural grassland and rangeland with strong heritage value. From now on, let's look at the high altitude areas. First of all, the humid mountain areas characterized by an altitude of less than 2000 m absl and a dominant place in permanent grasslands (+ 80% of UAA). The dairy production is highly famous for cheese making, these areas are specialized in dairy except for the Massif Central where suckling to weanling systems are also important. In high mountain areas, livestock are transhumant with the seasonally use of summer pastures for grazing and often benefit from agro-tourism and high value-added products.



Herbivore stocking rate

In 2010, the average herbivore stocking rate in France was 1.2 LU / ha of forage area (FA). Stocking rates are highest in the lowlands and piedmont regions where milk production is important. This phenomenon is exacerbated when there is competition on arable land with high value-added crops (potatoes, sugar beet, etc.) as in the north of France. Overall, the northern half of France benefits from favourable pedoclimatic conditions and can support above average stocking rates. Areas where suckler herds are thriving have lower stocking rates and are often located in disadvantaged areas . In the humid mountain regions, the overall stocking rate is about 0.9 in relation to grass growing over a short period. Pastoral and high mountain areas have the lowest stocking rate with less than 0.7 LU / ha FA.

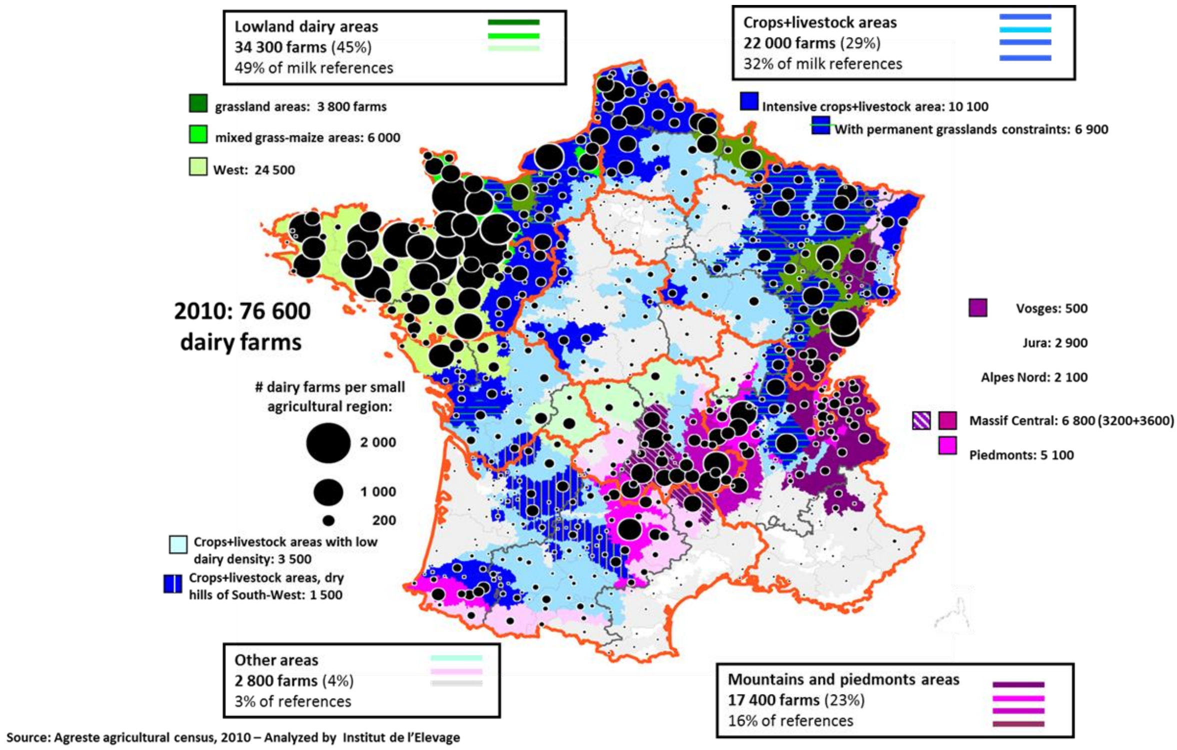


Herbivore stocking rates LU/ha FA (GEB - Institut de l'Elevage, 2013)

Livestock farming system utilising grassland

a) Dairy herd

The establishment of dairy cattle farms follows a form of "horseshoe" starting from the West, where the density of exploitation is the most important, through the integrated crop-livestock areas of the north and the east and end in the south-west of the Massif Central.



Classification of French dairy system (source: Agreste, RGA 2010, analyzed by Institut de l'Elevage)

Amount of milk produced

In 2014/2015, the milk collected in 65,600 farms was quantified at 25.1 billion litres, an average of approximately 383,000 litres of milk collected per farm. Since 2007, the average amount of milk collected per farm has increased by about 18,000l per year, while at the same time the number of farms collected has decreased by about 4,000 per year (FRANCEAGRIMER, 2016). Over this period the collection followed a slight increase. The seasonal variation in production is about 20% between the highest collection period (May) and the lowest period (September) (GEB-Institut de l'Elevage, 2018). The majority of milk collected comes from lowland areas (51.6%) and mixed-livestock areas (31%) compared to only 15% from mountain and piedmont areas. The tendency reverses when it comes to collecting milk to produce high value-added products (PDO, PGI). In fact, 87% of PDOs come from mountain and piedmont regions. France has 28 cheeses, 2 creams and 3 butters registered as dairy cow

PDOs, to which are added PGIs of 9 cheeses and 1 cream. In 2017, about 11% of the milk collected is used for PDO and PGI products, respectively 10.3% and 0.9%.

Contribution of areas to dairy production and their productivity per forage area (Brocard *et al*, 2015)

Areas	% farms	% deliveries	% specialized	Milk per Forage Area (l/ha)	% dairy PDOs
LDAs	46.5	51.6	37	6,600	3
West	*33.2*	*37.3*	*42*	*7,000*	*1*
CLA areas	28	31	23	7,400	4
intensive	*13.4*	*14.7*	*22*	*8,600*	*2*
MPAs	*22*	*15*	*67*	3,700	*87*
Jura	4	3.2	84	*3,000*	38
Other areas	3.5	2.4	41	5,300	6

Dairy herd size

Before the introduction of milk quotas (1983), France had 7.2 million dairy cows versus 3.8 million in 2017. Over this period the decline was a slow but continuous process. The mountains and piedmonts areas have been less affected than lowlands nearby crop areas. This is explained by the presence of higher value-added products in these regions that allow a less competitive and more robust situation for farmers. The decrease in the number of dairy cows did not affect the overall volume of milk collected thanks to improved individual performances.

Prim'Holstein are by far the most common breed in France, 2.4 million, followed by Montbeliard and Normand breeds that counts for almost 1 million cows. PH gives more milk per cow but the two other breeds give more added-value. Crossbred cows are still uncommon.

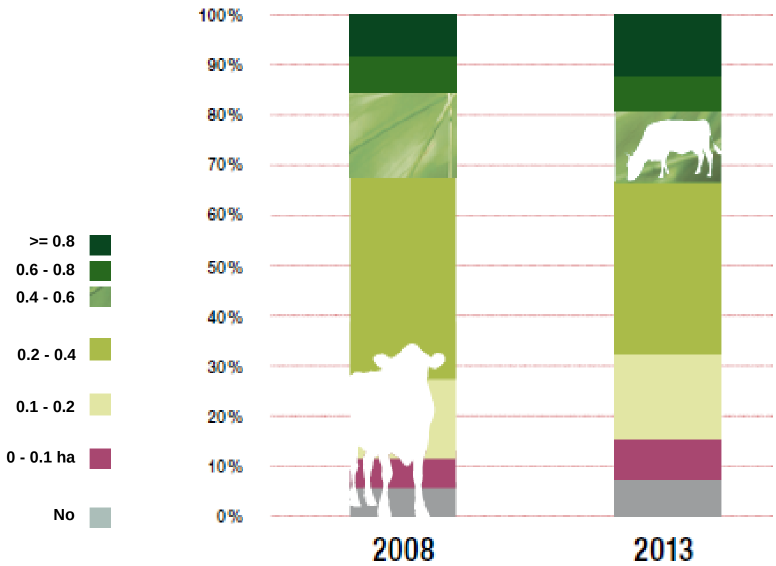
Nearly 70% of the farms have less than 60 dairy cows but 75% of the dairy cows are owned by farms with more than 50 dairy cows. In 2018, 11% of farms have more than 100 dairy cows.

Milk production per cow

Depending on the feeding systems, production per cow varies for the 6,000L in lowland grazing systems with 1 tonne of concentrate up to 8,500L with 1.6 tonnes of concentrate and 44% maize silage in the annual ration for integrated crop-livestock systems. Mountain and piedmont areas have a milk yield per cow that is slightly higher than the lowland grassland system but with a higher proportion of concentrates in the diet (225g / l vs 166g / l). These averages per cow hide large variation in production within these groups. (Observatory of the feeding of dairy cows, 2015).

Accessibility of grazing area

In France, grazing is practiced by 92% of dairy cows, 87% graze more than 170 days per year and 71% of farms offer more than 0.2 ha of pasture per cow. The contribution of grazing in the annual ration of dairy cows varies from 10% or 700kg DM for systems maximizing maize silage versus 31% or 1,800kg DM for grassland systems. French dairy farms have on average 31 hectares of permanent grassland and 22 hectares of temporary grassland. There are, however, significant disparities within and between dairy areas. The tendency is for herd expansion (+ 2 dairy cows / year on average per farm), however the accessibility of grazing areas does not follow the same path. Land expansion is needed for growing home forage but it often happens far away from the milking shed and overall the accessible grazing area per dairy cow decreases over the years. As a result, the larger the herd, the lower the contribution of grazing in the diet. On the contrary, grassland systems with more than 0.8 ha accessible grazing area per cow have increased in proportion. It could be related to the increase in organic dairy farming.



Accessible grazing area per dairy cow and its evolution (Observatoire des élevages laitiers, 2018)

Rise in automatic milking system

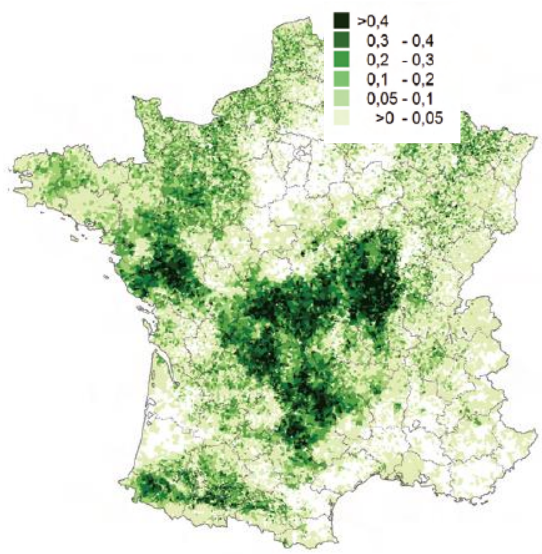
In France, as in other dairy countries, AMS are growing, about 4,800 in 2015. For every new milking parlour installation, one out of two is a milking robot since 2011. The setting up of a robot is often accompanied by a decrease in grazing, and may sometimes stop. In 2017/18, 34% of AMS are fully housed. Though many studies have shown the ability to keep grazing sustainably with a milking robot.

Organic dairy farming

With the past milk price breakdown, there has been an increase in conversion to organic dairy farming. In 2016, 2 500 farms were organic, mostly located in West and humid mountain areas where grasslands are growing for longer during the season. With an average of 48 cows per farm, the milk volume sets at 230,000 litres per farm. In 2019, forecast is almost 1 billion litres of organic milk. This would mean an increase in milk collected of 75% between 2016 and 2019. So far, demands for organic products in France have always absorbed the increasing production.

b) Suckler herd

The suckler herd is bound to the origin basins of the two main breeds which are Charolais and Limousin. Therefore suckler cows are located in the traditional Charolais and Limousin breeding area, which constitutes the grassland area of the Nord Massif Central with 1.01 million of suckler cows. Following are the intensive zone of the West (530,000 cows) with a high density of suckler cows, also the piedmonts of south west Massif Central and of the Pyrenees. Suckler cows are spread in the grassland and forage areas.



Number of suckler cows per ha in townland (GEB - Institut de l'Elevage, 2013)

Herd size and its evolution

Before the milk quotas there were 2.9 million of suckler cows. A strong growth happened until the 2000s with a national herd now stable of about 4 million suckler cows. All regions have been affected by this phenomenon. Half of this growth was in the dairy zones and half in the traditional areas. In 2018, Charolais is the first breed commonly found with 1.45 million dams, followed by the Limousin with 1.1 million cows then Blond d’Aquitaine with 0.48 and finally the more rustic breeds Salers and Aubrac who both account for 0.4 million cows.

In 2017, farmers who possess suckler cows are about 85.000, ten years ago they were twenty thousand more. Among them 44% have less than 29 cows. But 1.9 million suckler cows are held by 21% of farmers with herds bigger than 70 suckler cows.

Characteristics of the production

The meat production systems in France are mainly breeders and not finishers. This reflects the fact that the vast majority of farmers hold a herd of breeding cows, whose main purpose is to produce late-weanlings and cull cows. The most represented system, about two thirds of the farms, produces lean animals to be fattened in specialized workshops. Such workshops exist in France, but are mainly located in neighbouring countries, particularly Italy and Spain. These breeders sell weanlings for store market and cull cows for butchery. In the Charolais Basin, some weanlings are kept longer and fed with cut grass and cereals to sell heavier weights for the store market. Traditionally in this region, a lean young bull kept grazing until the end of its second spring before being sold to a finisher.

About 20% producers, mainly in lowlands area, have developed suckling to beef system. By creating a fattening workshop, breeders increase the amount of meat sold by LU on the farm. These workshops goes hand by hand with the introduction of maize silage used for fattening bulls born from the suckler cow herd. They have come to replace the more traditional suckling to steers beef systems because they are faster to finish.

Steers are not much present anymore in France. They rely on grassland systems. Maize is almost not present, especially for the image of the final product. These systems are not very demanding in terms of labour because pasture is predominant in the diet. They are usually found on large farms with constraining land.

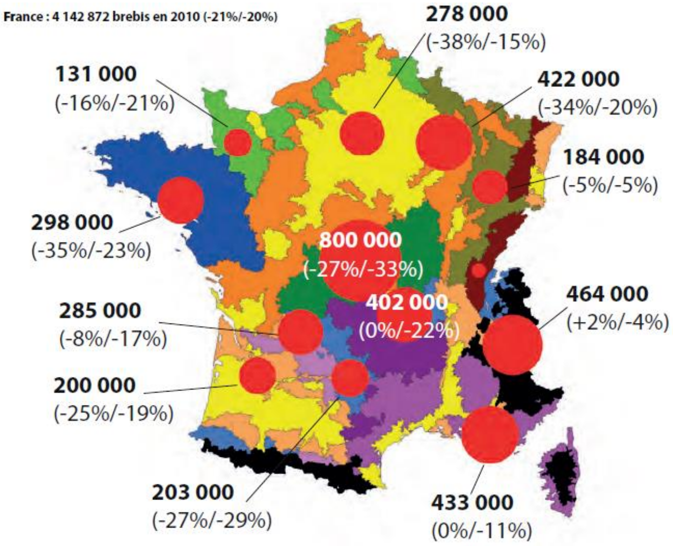
Last is the system producing suckling veal. This system is mainly found in the south-west of France, the traditional region for this product. Calves stay in-house while cows are grazed or fed separately, the suckling happens twice a day. The practice last during 3 to 5.5 months for a carcass weight between 85 and 170 kg. The margin is the highest of all beef production systems with equivalent stocking rate but is very time-consuming. This system of production is aimed at producers who, having a forage surface constraint, cannot move towards production of weanlings.

c) Sheep

1) Dairy

Sheep production is regionalized and consistent with the environment and animal production. Sheep farms specializing in dairy production are mainly located in Roquefort area, with a high added-value PDO and in western Pyrenees, in particular the Ossau-Irraty PDO. There are also flocks in south east of France that gets value from cheese-making on the farm.

In 2010, the number of farms with dairy sheep holdings was 5,000 holding with 1.4 million ewes. These farm produced 270 million of milk and two thirds are collected within Roquefort area. The amount of milk collected have been steady for ten years and was increasing before that.



Number of ewes for meat in 2010 and their evolution 1988-2000/2000-2010 (RGA 1988, 2000 and 2010, analyzed by Institut de l'Elevage)

In Roquefort area, farms have an average of 81 ha of UAA, of which 80% is dedicated to forage production. Permanent grassland accounts for 19% of the forage area, while temporary grassland, mainly grass-legume with high alfalfa content, accounts for 79% of the FA. The non-forage area is dedicated to growing grain to produce energy concentrate and straw for the flock. The flock is growing steadily in these farms and the average stocking rate is 1.3 LU/ha, this represents about 300 ewes per farm in average. In this region, the gross margin is highly dependent on milk production per ewe, average is 261 litres per ewe.

In western Pyrenees, farm structures are smaller, with an average of 33 ha. Forage area represents 98% of the UAA. Permanent grasslands account for 59% of the FA and temporary grasslands account for 36%. Maize is present in every other farm and occupies less than 10% of the FA. The average flock is 63 LU (about 225 ewes) for an average stocking rate of 2 LU/ha. These strong stocking rates are consistent with the pedoclimatic conditions which make it possible to ensure an important forage production and well distributed over the year.

2) Meat

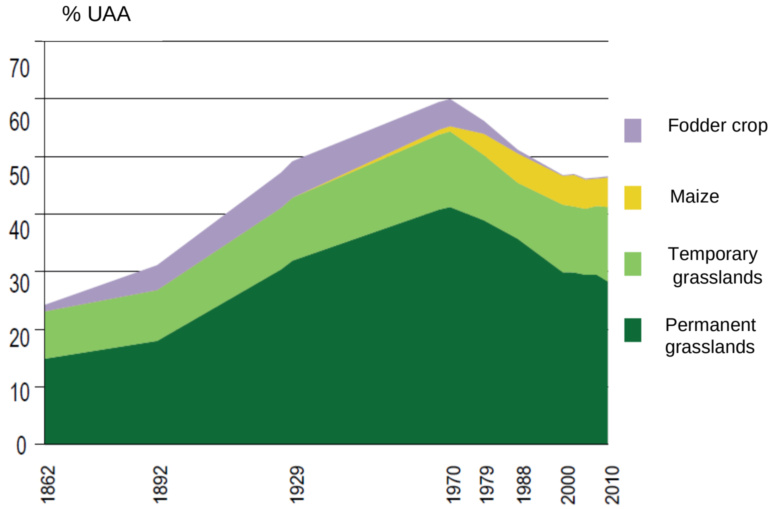
The farms with sheep meat production are concentrated in the southern part of the national territory. In contrast to the dairy situation, lamb production has suffered since 1980 from a sharp decline in the number of farmers and the number of ewes. This is partly explained by a specialization of farms which gave up mixed farming for only cropping or milking or even increasing suckler cow herds.

Many farms have small flocks as an illustration: 66% of the total ewes are possessed by 16% of the farms with flocks above 200 ewes. In 2017, only 3.6 million are remaining in the national flock when there were 6.5 million in 1988. Thus the meat sheep sector is not in good shape for coping with the future needs: post-Brexit, decline in consummation, increase supply of domestic market (45% today), attract young farmers, maintain natural area for habitat conservation by grazing. When analysing numbers of sheep farms, two major characteristics are essential for economics. The first characteristic is the importance of lamb mortality, with very large differences between farms, in 2009, the median value was 16%. The second characteristic is the strong relationship between the margin on feed cost per ewe and the productivity, expressed in kilograms of lamb per ewe.

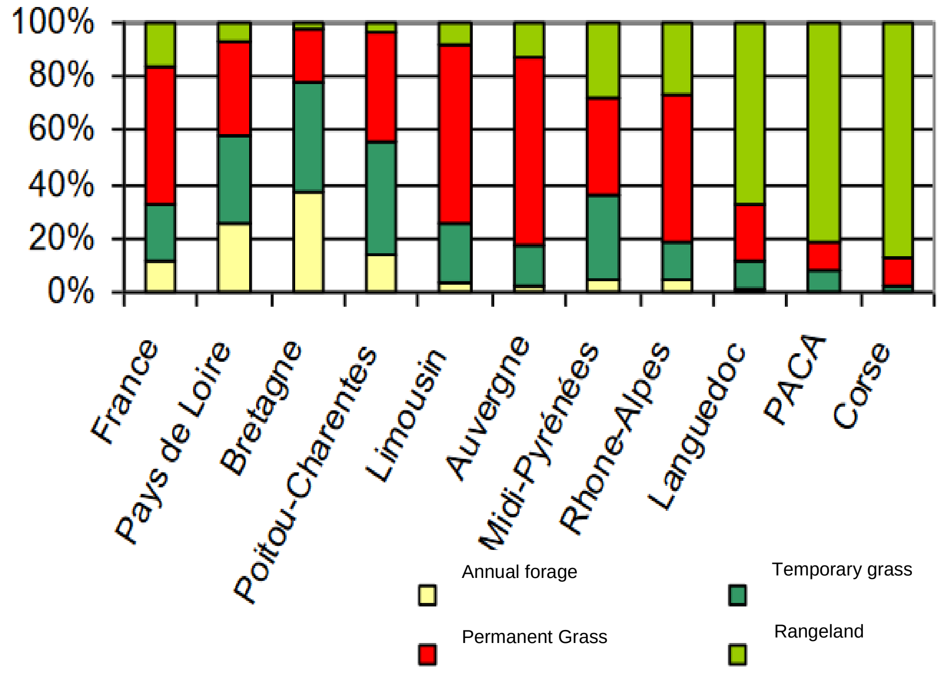
Between regions, stocking rate vary from 1.1 LU/ha FA in grassland areas in Charolais Basin to 2.5 LU/ha FA in integrated crop – livestock areas, thanks to higher content in the diet. The latter system may also use cover crops to feed the ewes at times when there is no commercial crop. Hay is the main form of forage preservation, except in mixed systems where silage is available. There is a strong contrast between grassland specialists with very little grass stock, sheep production relying heavily on grazing, and those in high mountain areas with large stocks.

Importance of grassland in France

Over a period of 5 decades, the decline in grasslands and forage crops is clear, with almost total disappearance of fodder crop (fodder beet), a very pronounced decline of legumes in pure crops, a significant decline in permanent grasslands, especially areas still in productive grassland that are neglected, the rise of maize silage, and a slight increase in temporary grassland.



Evolution of the forage area in France (GEB - Institu de l'Elevage, 2013)



Composition of forage area in regions (Huyghe *et al*, 2015)

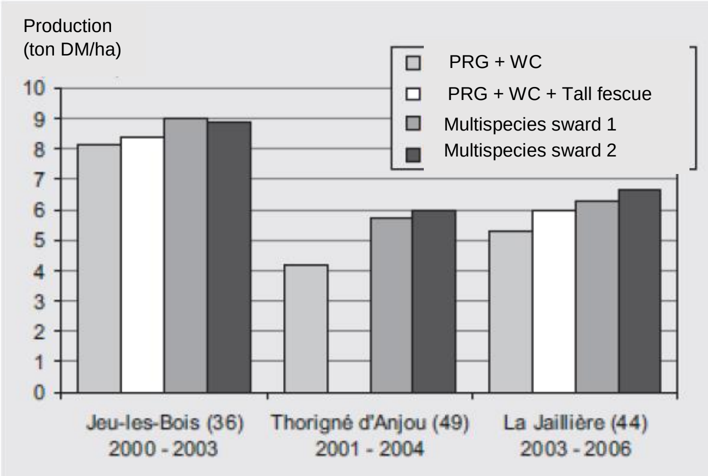
The temporary grasslands composition have deeply changed with a very large proportion of current areas in mixtures and associations, whereas monocultures predominated in 1960.

The French territory appears very heterogeneous with regard to the different types of grasslands that one cultivates there. In the western and central-western regions, annual forages and temporary grasslands predominate. In mountain regions, it is mostly productive permanent grassland that supports the many herds of cattle. Finally, in the South-East, the rangelands (low productive permanent grassland) constitute the bulk of the grasslands.

1) Temporary grasslands

In 2001, grass-legume mixture accounted for about 45% of the area sown to temporary grassland. The PRG and WC mixture alone accounted for 28% of the area of temporary grassland. White clover is nearly always sown within temporary grasslands, especially for grazing. Multispecies swards, with minimum 2 grass species and 2 legumes, accounted for 18% of these grasslands with a very large regional disparity: they represent 3% of the temporary pastures of Brittany and 56% in the Limousin.

Studies comparing multispecies sward to mixture of perennial ryegrass and white clover have shown yield advantage for the multispecies sward of about 1 ton DM per ha. This advantage tends to be even greater during drought period. On the nutritive point of view, they have globally slightly lower energetic (-0,05 UFL) and crude protein values (-1% CP). This effect is emphasized during heading date because grass species head at different time make the optimum stage harder to obtain for the whole sward.



Yield comparison of multispecies sward versus grass-legume mixture (Protin *et al*, 2014)

2) Permanent grasslands

Permanent grasslands are an important part of the forage areas in France. However, if we know that they are favourable to biodiversity and that in general species richness is high, their actual botanical composition is poorly known. Launay *et al.* (2011) studied in 2009 and 2010 a network of 190 permanent grasslands. These permanent grasslands were used in different livestock system (beef, lamb, dairy cows) and on a wide range of pedoclimatic conditions, from Atlantic coast to highland meadows, up to 1,200 m. The annual production of material, based on late spring, summer and autumn cuts, was estimated at 6.2 t / ha / year, with a very large variation, with 25% of meadows producing less than 4.2 t / ha / year and 25% producing more than 8.1t / ha / year. Spring production provided 75% of average annual production on these permanent grasslands. Summer and autumn productions are more contrasted between regions. In fact, over the 2 years of this study, the regrowth was too weak to justify a harvest in more than 25% of the grasslands.

On the whole set of permanent grasslands, digestibility of organic matter averaged 77% at the beginning of spring and 64% at the end of spring, which correspond to a pasture stage for the first and end of heading for the second. The average protein content was 17% at the beginning of spring, while at the end of spring, at 9%.

The combined analysis of dry matter production, its distribution throughout the cycles and the feed value confirmed the negative relationship between production and nutritive value, which decline more rapidly on the most productive grasslands.

As a result, five main characteristics differentiate feed value from permanent grassland (Baumont *et al*., 2012):

- the ability to have a strong spring production and in total over the year. These permanent grasslands can provide forage stocks and / or be a great resource for spring grazing;
- the ability to grow in the summer and fall, which is partially independent of the spring production potential;

- the ability to produce high quality forage for early harvest and regrowth. These grasslands which are rich in legumes are then a source of quality forage, but provided they are grazed at fairly early stages;
- the ability to produce quality forage in late spring. These grasslands, rich in legumes and broadleaf, have few grasses and low productivity;
- stability of quality throughout the spring. This has been encountered in the case of grasslands with low dry matter production with a significant presence of non-leguminous dicotyledonous, these grasslands can then be utilised for long periods without large variation in quality.

3) Grazing strategy

In France, there are many terminologies to characterize the forms of grazing practiced. Often used are set-stocking and rotational grazing.

Some technical references of set-stocking:

- Grass height (compressed) between 6 and 8 cm
- Between 0.3 and 0.8 ha of available area per animal
-

Pros	Cons
- Little infrastructure need (fence, pathway, water trough) - Simplification of work - High individual performance	- Higher land requirement per animal (+ 20%) - Less production per ha - Sensitivity to dry spell

Rotational grazing is based on the principle of a relatively short grazing time per paddock and a long resting time of the pasture depending on the season to offer quantity and quality of grass. It is necessary to multiply the fenced paddocks.

Some technical references of rotational grazing:

- Rest grass between 18 and 21 days in spring, 28 – 35 days in summer when growth slows down
- Entrance height: between 8 and 15 cm
- Residual height: between 3 and 6 cm (depending on entrance height)

Pros	Cons
- Increase the pasture utilisation - More stock harvested on the same area - Respects the growth curve of grass	- High infrastructure cost (fence, pathway, water trough) - High skill for paddocks management - Production variation during grazing (except if less than 1 day)

In the end, good grazing management is possible regardless of grazing strategy but it needs good observation and adaptation to grass growth.

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7.8 Italy

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The country

Italy is a peninsula extending far into the Mediterranean Sea. The estimated resident population is 60.4 million people (data 2017), unevenly distributed. In fact, the Po Valley, in Northern Italy, and the metropolitan areas of Rome and Naples, in Central and Southern Italy, are densely populated. On opposite, Alps and Apennines highlands, and the island of Sardinia are very sparsely populated. The average population density is 201 inhabitants per square kilometre, a value higher than that of most Western European countries.

The national area is 301,338 square km. Its territory is mostly hilly (42%) and only 23% are plain areas, prevailingly concentrated in the Po Valley, the most important Italian plain (44,000 square km). The rest of the territory are mountain areas (35%). The Alps, in the northern border, and the Apennines, which form the backbone of the entire peninsula and the island of Sicily, are the most important mountainous systems. Italy lies in the temperate zone but there is a strong climate variation between the northern regions bordering the European continent, and the South, surrounded by the Mediterranean Sea, due to the considerable length of the peninsula (1,200 km). Three main biogeographic areas dominate the country:

- (i) the Alpine area, which has a continental mountain climate;
- (ii) the continental climate area, mainly represented by the Po Valley, characterized by hot summers and severe winters;
- (iii) the Mediterranean region, covering the Central and South Italian regions and the islands of Sicily and Sardinia, which most important climate trait is the concentration of rainfall during the relatively mild winter season and its total absence during hot summer, associated to a large intra- and inter-annual variability.

Italy shows a variety of soils as well, originated from several types of parent materials, at different altitudes, under different climatic conditions in preceding eras. Dark-brown podzols are very common in the Alps, where rainfall is heavy. In the Apennines, brown podzolic soils predominate, supporting forests, meadows and pastures. Rendzina soils are characteristic of the limestone and magnesium limestone mountain pastures and of many meadows and beech forests of the Apennines. Sparse red-earth soils, rocky soils, clays, dune sands and gravel can be also found.

The agricultural sector and the animal husbandry with the focus on ruminants
(modified from Lombardi *et al*., 2012 and Porqueddu *et al*., 2017)

Italy enjoys an abundance of agricultural resources and its potential productivity is high. It is a world leader in olive oil production and a major exporter of rice, tomatoes, wine, fruit and vegetables. Despite this, its agri-food trade balance is negative, and

Italy is a net importer of agricultural raw materials but a net exporter of processed foods (Centro Studi Confagricoltura data, 2018). Concerning the zootechnical sector, meat production is not sufficient for internal demand and meat is imported from other European countries, particularly from Ireland and Germany. Italy is also quite weak in the dairy farming sector and its milk delivers contribute with 8.2% to total European milk delivers. Italian self-sufficiency in milk is 84.5% (CLAL data, 2017). The total available milk is mainly processed into PDO cheese (Figure 1) of which Italy is the main European producer. The exports of dairy products concerns 29.3% of the national delivered milk, expressed in milk equivalents, equal to 4.7% of the European exports.

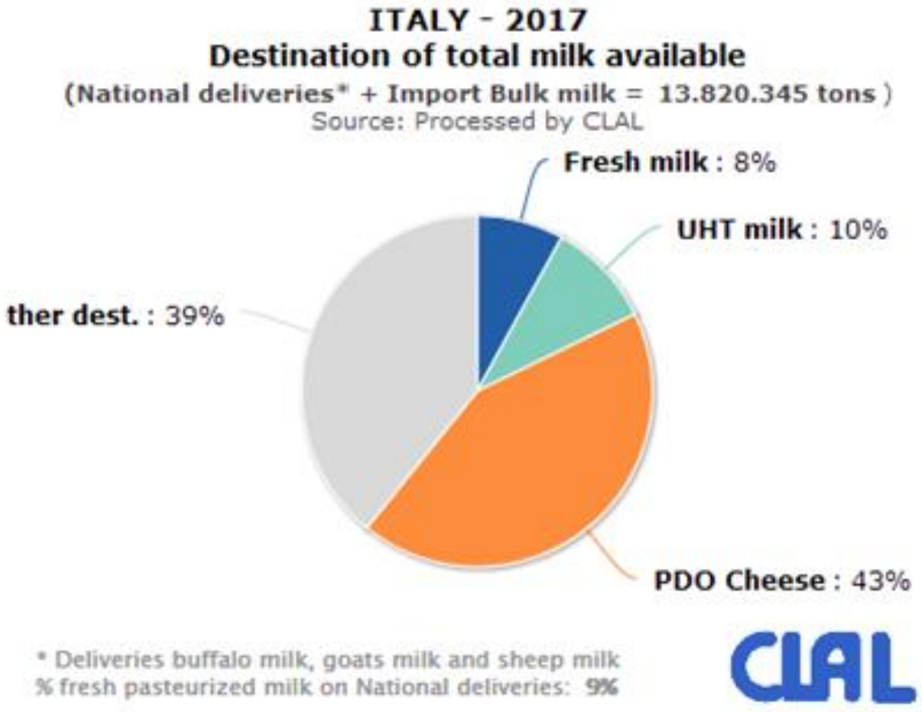

Figure 1. Destination of total milk available in Italy. CLAL data, 2017.

The ruminant population consists of 6 million heads of cattle, 7 million heads of sheep and 1 million heads of goats, which represent 7, 8 and 8% of the total European heads, respectively. Dairy cows prevail among cattle (Italian Holstein and Brown Swiss breeds), followed by double purpose milk-beef breeds (e.g. Italian Simmental, Modicana, Tyrolean Grey), and, finally, specialized beef cattle (usually indigenous cattle breeds, e.g. Piemontese, Chianina, Marchigiana, Romagnola). The most important sheep breeds are Sarda and Comisana, specialized in milk production. The number of sheep showed a negative trend in the last seven years (-8.66%), while the number of cattle (+8.9%) and goats (+0.93%) increased.

Table. 1 Evolution of animal heads per category and milk production in Italy. Eurostat data (2017) and CLAL data (2017).

Animal heads									
Category	**Year**								**2017/2010 (%)**
	2010	***2011***	***2012***	***2013***	***2014***	***2015***	***2016***	***2017***	
Living bovine animals (nr. x 1,000)	5,833	6,252	6,252	6,249	6,125	6,156	6,315	6,350	+8.87
Dairy cows	1,746	1,755	2,009	2,075	2,069	2,057	2,060	2,040	+16.84
Buffalos	365	354	349	403	369	374	385	401	+9.77
Beef animals				2,084	2,014	2,042	2,085	2,123	*+1.87
Live sheep	7,900	7,943	7,016	7,182	7,166	7,149	7,285	7,215	-8.66
Milk ewes	5,416	5,469	5,302	5,247	5,142	5,137	5,206	5,130	-5.29
Live goats	983	960	892	976	937	962	1,026	992	+0.93
Milk production									
Category	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***	***2016***	***2017***	
Raw cows' milk from farm (tons x 1,000)	11,399	11,298	10,876	10,701	11,037	11,161	11,524	11,950	+7.01
Ovine milk (tons)			406,177	383,836	372,526	397,500	424,840	427,430	+5.23
Goat milk (tons)			27,940	27,489	28,463	33,200	31,730	37,050	+32.61
Cow milk yield (kg year^{-1})							6.326		
Sheep milk yield (kg year $^{-1}$)							172**		
Goat milk yield (kg year^{-1})							135***		

** Data are referred to lactating ewes of the Sarda breed; ***data are referred to goats bred in Sardinia.

Currently, 4.2 million living bovine heads and 1.2 million dairy cows (65 and 60% of the national amount, respectively) are raised in the northern regions with intensive systems, where 40% of livestock holdings can be found. On opposite, 78% of buffalos and 72% of sheep and 64% of goats are bred in South Italy and main islands (Sardinia accounts for 45% of sheep heads and 22% of goats).

The number of livestock holdings is about 155,000 (Eurostat, 2016). Their number dropped drastically from 2010 (-65%), and the decrease concerned especially the holdings located in mountain areas of Central and South Italy and the small-sized farms. On opposite, the larger size holdings (>500 Livestock Unit (LSU)) showed an increase in number (+9%), indicating a deep restructuring of the livestock system in Italy. The average farm size is 9 ha, but high sized farms can be found in mountain areas (13 ha), and smaller farms in hilly and lowland areas (8 and 6 ha, respectively). Significant differences between northern and southern regions are also seen in the number of heads per farm: an average of 54 (northern) and 28 (southern) heads of cattle are bred per farm. The number of dairy cattle per farm in Northern Italy is double than in southern regions (33 vs. 17), while there is one-third the number of small ruminants in northern regions compared to southern regions (31 and 14 vs. 106 and 39, for sheep and goats, respectively).

With regards to the altitudinal distribution of cattle livestock holdings, 74% of them are located in marginal areas (34% in the mountain and 40% in the hilly areas). However, these holdings account for less than half of the national livestock figures, and there are major differences between northern and central-southern regions that are most likely due to the farming system in place. In fact, in Northern Italy, 44% of livestock holdings are concentrated in the Po Valley, where an average of 130 heads per farm is raised. The number of heads per farm decreases with altitude: farms in hilly areas rear an average of 35 heads of cattle per farm, while the average for farms in the mountain areas is just 19. Over the last fifty years, the structure of agricultural holdings has been highly affected by socio-economic changes. A generalised reduction of agricultural surfaces has been observed all over the country, but while the agricultural area declined by 30%, 50% of the surface of permanent grasslands and meadows was lost.

Over the same period, the number of agricultural holdings decreased by 66%. Dairy farms were especially affected by drastic structural changes, with their numbers declining by 80%, while the number of dairy cows declined by only 35%. The heads per farm increased from 8 to 22. The number of sheep and goat farms dropped by 47% and 71%, respectively, while the number of heads of both the species was almost stable. Such changes resulted in an increase in heads per farm.

Grassland types

The Italian Agricultural Utilised Surface is equal to 11.29 million ha, about 40% of the national area (Eurostat, 2017). Grasslands cover about 6.5 million ha.

Table 2 – Evolution of the grassland areas in Italy.

Grassland type (ha)	**Year** 2005	2007	2010	2013
Fodder crops – temporary grasslands	955,380	946,570	1,082,490	1,024,950
Fodder crops - Green maize	215,320	220,380	233,730	274,830
Other green fodder	832,870	849,620	835,360	914,460
Other fodder crops - leguminous plants			103,560	105,510
Fallow land	473,420	494,220	547,720	365,310
Permanent grasslands and meadows	3,346,950	3,451,760	3,434,070	3,316,430

Most grasslands are permanent meadows and pastures (table 2), which cover 3.3 million ha (more than 50% of the total grassland area). The southern regions and main islands account for about half of national grassland areas, represented by permanent pastures. In the northern regions, permanent pastures account for 60% of the grassland area, but permanent meadows are widespread due to more favorable soils, land morphology and precipitation distribution.

The majority of permanent meadows and pastures is located in mountain areas (60%), reaching 90% in Alps, and hilly areas (33%). The Apennine Mountains show a lower proportion of permanent meadows and pastures (50%), without differences

among northern, central and southern regions. In lowlands, permanent grasslands are scarcely present and temporary grasslands, represented by annual fodder crops (maize-silage, barley, oat, sorghum, Italian ryegrass, vetch, berseem and crimson clover) and temporary grassland (alfalfa, sulla, sainfon, white clover, red clover, grasses and their mixtures) prevail.
Permanent grasslands underwent a gradual reduction from ‘90s to 2000, when more than 340,000 ha were dismissed, while from 2000 to 2013 their area remained stable (EUROSTAT, 2018). The largest decrease involved pastures and meadows. Currently, permanent grasslands and pastures are widely diffused in the main islands (Sardinia and Sicily, 40.7% of their used agricultural area (UAA)), followed by the regions of North West (32.5%), North East (24%), Southern Italy (20.6% of their UAA) and Central Italy (18.5% of UAA) (ISTAT, 2016).

Grass yield and grass quality
Due to the several bioclimatic areas and soil variability, Italian grasslands show a great variability in terms of production and quality as well as farming systems, where animal breeds, forage resources and level of intensification are adapted to specific environmental conditions. Despite several constraints (i.e. climate, morphology, small size of farms and flocks, lack in the technical assistance), Italian grassland production is rather important, showing interesting and, sometimes, original models of adaptation to the specific environmental conditions, which are certainly among the most difficult in Europe.
Grassland average annual dry matter yields are generally quite low in the rainfed Mediterranean zones, ranging between 1 and 3 t ha^{-1}, but can reach up to 10-15 t ha^{-1} in the lowlands in North Italy under continental climate. This great variability in terms of forage production can be represented by the following situations: marginal lands (nearly 35% of total acreage); intensive agricultural areas (nearly 15%); intermediate areas between extensive and intensive (about 50%).

Normally, in **marginal areas** there are no temporary grasslands or just small surfaces. Grazing is largely dominant, and the permanent pastures are the main forage resources outside of woods. Generally, in these areas it is possible to find two different systems. In the uplands, utilization by grazing is limited to short periods during summer with dairy cows in the Alps and with beef cattle, sheep and goats in the upper part of Apennines and islands. In the more typical Mediterranean areas, there are very long periods of grazing with low stocking rates. The agro-pastoral systems, widespread in interior hilly areas with little mechanization, are based on diversified resources, semi-natural grasslands, and improved pastures coexist in the better areas. Traditionally, also wooded grasslands, with up to 10-40% tree and shrub cover are used to support livestock production in these regions. These silvopastoral systems are based on woody pastures, but grazing-animal breeding is often associated to other agricultural activities to improve the income of farmers (e.g. cork production in Sardinia).

In the **intensive agricultural areas**, we find the most important and productive animal husbandry (e.g. dairy cows in the Po Valley and in other small scattered areas along littorals and Apennine valleys). The common characteristic of these areas is the zero-grazing system with the use of high amounts of supplements. The intensive forage production in the Po Valley is based mainly on corn for silage, which can also enter in the forage production systems as summer crop (double cropping) following winter cereals (e.g. barley and wheat) or Italian ryegrass as temporary grassland (Figure 2 and 3). Corn for silage is supported by rotated meadows of lucerne, Italian ryegrass and ladino clover or cocksfoot, tall fescue with lucerne and ladino clover, or to lesser extent by permanent meadows. The increase of surface area sown with sorghum confirms the important role that this crop plays in the diversification of the farm production. The meadows are widespread in the areas where corn cannot be grown due to pedological limitations.

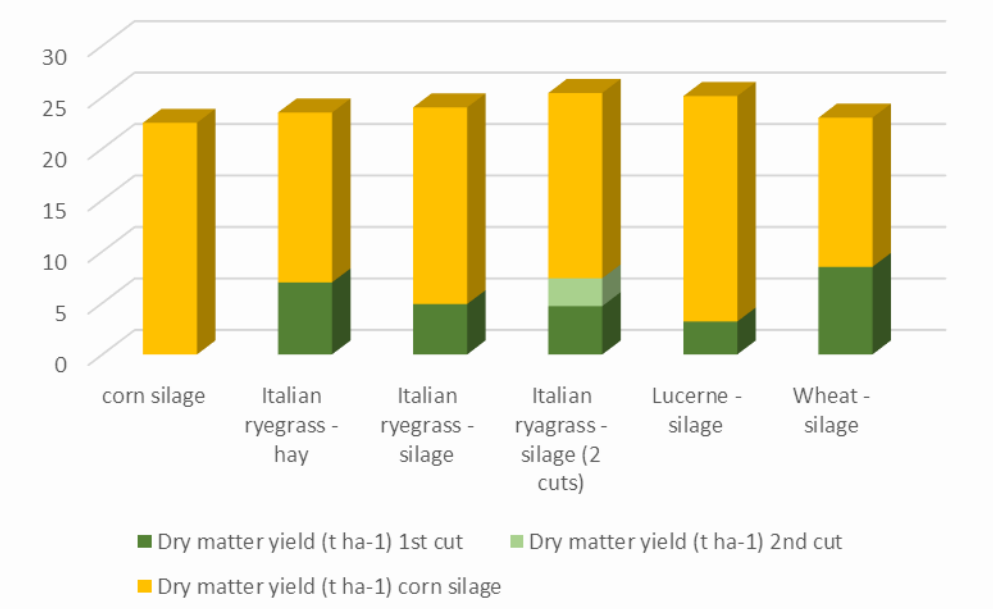

Figure 2– Double cropping for the intensification of corn for silage systems (Borreani and Tabacco, 2016).

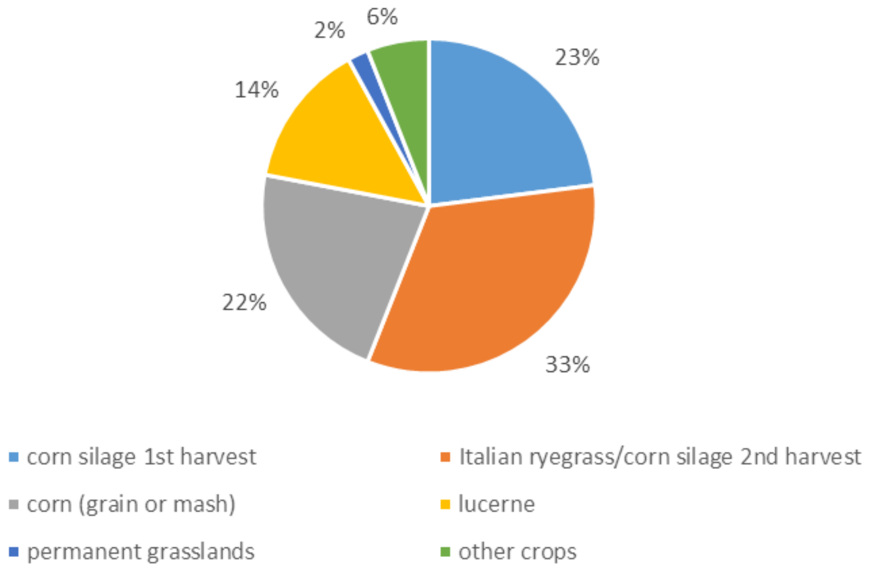

Figure 3 - Recurring forage systems in Po Valley for dairy husbandry (Borreani and Tabacco, 2016).

The **intermediate areas**, between marginal and intensive zones, are where temporary and permanent grasslands coexist. They are the most spread out in the low mountain, hilly lands and rainfed plains with mainly beef cattle or dairy sheep. The forage systems are quite variable, depending on the farming systems. In the coastal plains and in the dry low hills were mixed crop-livestock systems are present, the base of the feeding systems is a combination of annual forages and cereal stubbles. In hills that can be mechanized, feeding systems based on permanent grasslands and the use of hay storage and pastures are diffused. Production systems vary from those excluding grazing up to the sharp separation of grazed areas and mowed areas, and systems based on the utilization by grazing of the regrowth of grass-legume leys ("prato-pascoli"). The seasonal fluctuation of the grassland production requires hay and/or silage reserves in order to face difficult periods for feeding animals.

Grassland performances in **Mediterranean environments** are negatively impacted by some physical constraints, which complicate the mechanization of soil tillage, and by climate characteristics. In fact, summer drought coupled with high solar radiation levels, cool winter temperatures during the growing season, and highly erratic and variable rainfall limit grassland productivity. As adaptation to summer drought, annual species prevail in semi-natural Mediterranean grasslands. Their growing season ranges from 4 to 10 months, depending on rainfall amount and timing and plant tolerance to water deficit (300 - 1000 mm), and it is characterized by two growing peaks in spring and autumn. Dry matter accumulation ranges between 110 kg ha^{-1} day^{-1} in the most favourable season (spring) and 20-40 kg ha^{-1} day^{-1} in autumn (figure 4 Caredda *et al*., 1992).

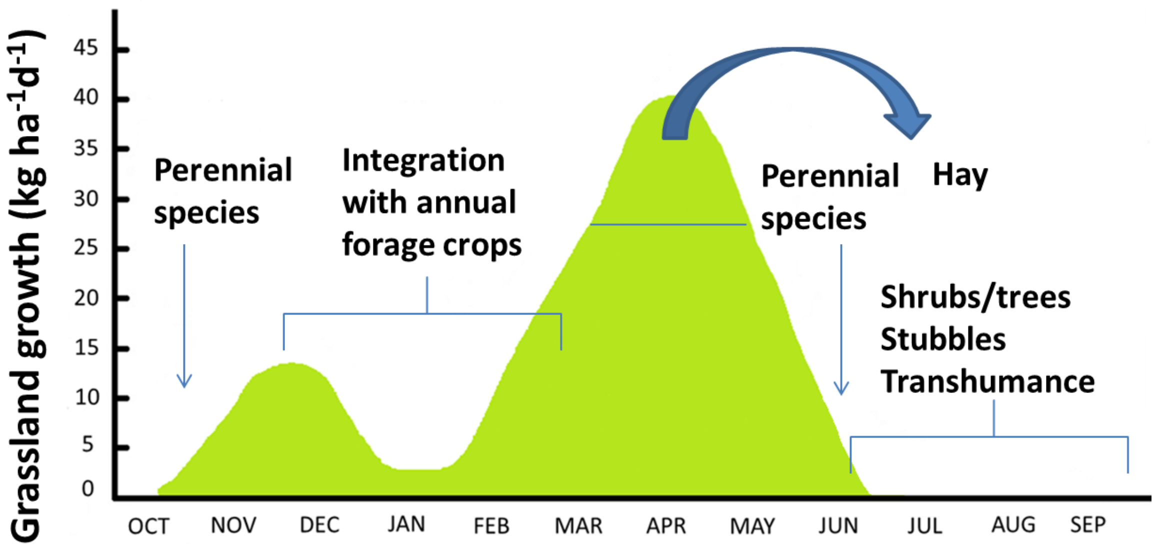

Figure 4 – Herbage production and integrations to grazing animal diets in Mediterranean areas.

Annual and inter-annual forage productions under rainfed conditions are usually extremely variable, but generally limited, and depend on grassland management and soil fertility. Typically, average dry matter yields range from 0.5-1.0 t ha^{-1} year^{-1} in semi-natural grasslands, which prevail in marginal soils, to 6.0-7.0 t ha^{-1} year^{-1}, in agriculturally improved grasslands (table 3, Huyghe *et al*., 2014). In grasslands subjected to shrub encroachment, herbage production declines with the increasing of shrub cover, as well as its nutritional value (Zarovali *et al*., 2007). In the latter case, an appropriate agronomic or grazing management aimed at controlling shrubs should be introduced to promote grassland renovation and conservation. In semi-natural grasslands, forage usually has a low quality, often worsened by a relative high rate of unpalatable species. A better forage quality can be attained by applying P-fertilizers once a year to boost annual pasture legumes production, but when their natural seed bank is not sufficient, the re-sowing with annual self-reseeding pasture legumes is appropriate (Porqueddu and Gonzales, 2006). The most used mixtures include 3-4 species and are based on subterranean clovers (*Trifolium subterraneum* L. *sensu lato*) and annual medics (*Medicago* species).

Table 3 - Grassland dry matter yield (DMY) (t ha-1) in six Sardinian sites (average of 5 years). Fertilization: 100 kg P_2O_5 ha^{-1}, 50 + 50 kg N ha^{-1} (from Bullitta and Caredda,1982).

Site	**Altitude** (m a.s.l.)	**Type of soil**	**DMY (t ha^{-1})**		**DM %**	**Extension of forage availability** (in weeks)
			Not fertilised	**Fertilised**		
BONASSAI	80	Limestone	4.23	8.23	95	+7
CHILIVANI	350	Alluvial	2.77	5.05	82	+7
BADDE ORCA	600	Trachitic	3.13	5.52	76	+3
PATTADA	650	Granite	4.44	6.33	43	+4
CAMPEDA	650	Basaltic	3.92	6.41	63	+3
S. ANTONIO	650	Basaltic	2.39	5.38	122	+8

To complement the insufficient pasture production in Mediterranean regions, annual temporary grasslands are widely exploited because of their high growth rates in winter and flexible use. Traditionally, mixtures of annual forage legumes and winter cereals (oat, barley and triticale) or grasses (especially Italian ryegrass, *Lolium multiflorum* Lam. ssp. *italicum* and ssp. *westervoldicum*) are used for short-term forage crops on arable lands. The most used legume species are common vetch (*Vicia sativa* L.), woolly pod vetch (*V. villosa* ssp. *dasycarpa* (Ten). Cav.), Persian clover (*T. resupinatum* L.), crimson clover (*T. incarnatum* L.) and berseem clover (*T. alexandrinum* L.). These temporary grasslands are exclusively cut for hay production or mowed after the winter grazing (one or more grazings per season). Often, farmers harvest forage with a delay which has negative consequences on quality. Recently, farmers have introduced some mixtures based on annual self-reseeding pasture legumes and winter cereals to extend the duration of temporary grasslands to two or three years. Among perennials, lucerne represents the primary temporary grassland species for neutral and alkaline soils. Very frequently, the seed of local ecotypes is utilized in pure stands as green forage, hay or dehydrated forage (3-4 cuts between June and October). Lucerne stands typically persist for 3-4 years under rainfed conditions or occasional irrigations, before a rotational crop is grown. Despite their wide-spread natural distribution in hilly areas, perennial legumes as red clover (*Trifolium pratense* L.) and birdsfoot trefoil (*Lotus corniculatus* L.), which are adapted to moderately acidic soils, have been little sown. The same is true for sulla (*Sulla* *coronaria* (L.) Medik.) and sainfoin (*Onobrychis* spp.), although there is renewed interest in each of these perennial legumes (Porqueddu *et al*., 2016). A few varieties of perennial grasses, particularly cocksfoot (*Dactylis glomerata* L.), tall fescue (*Festuca arundinacea* Schreb.) and bulbous canary grass (*Phalaris aquatica* L.), are sown in higher rainfall areas with deeper soils and are generally included in seed mixtures with annual or perennial legumes.

Grazing

In Northern Italy, generally, grazing is mainly carried out for a limited period of the year, from 2 to 4 months, in Central Italy, this phase can easily last up to 6 months, while in Southern Italy and Islands, the mild winters allow year-round open-air grazing. Both, continuous and rotational grazing, are applied, also rationed grazing is used limiting the time for access to the grassland (2-4 hours per day). In Table 4, the suggested values of grass height for entry and exit from the grazing sector in some grasslands used by sheep with rotational grazing are reported. The grazing system can also change during the year in relation to the farm structure, farm grassland resources, grass seasonal growth and animal physiological stage (Table 5). Hereafter, some of the most common grazing-based farming systems in the country are described.

Table 4 - Suggested values of grass height for entry and exit from the grazing sector in some grasslands used by sheep with rotational grazing (Molle and Decandia, 2005).

Pasture type	**Grass height (cm)**	
	Start	**End**
Italian ryegrass	15-20	3-5
Cereals	20-25	8
Lucerne	Start of blooming	3-8
Berseem clover	20-25	8-10
Subterranean clovers and annual medics	10-15	3

Table 5 - Sheep grazing techniques suggested for different grasslands (modified from “Prograze”, Molle and Decandia, 2005).

Dry pastures

Prevailing species	Growth phase				
	Stubbles (summer)	Emergence or resprout (autumn)	Growth start (winter)	Growth end (spring)	Beginning of heading/blooming (end of spring)
Lolium rigidum (self-reseeding)	Moderate grazing to eliminate stubbles	Reduce the stocking rate at the emergence of the seedlings to encourage their development up to 3-4 leaves	Continuous or rotational grazing with moderate stocking rate	Continuous or rotational grazing with high stocking rates to delay heading	Avoid intense grazing in order not to reduce the re-seeding.

Lolium italicum			Continuous or rotational grazing with moderate stocking rates starting when grass height is 20-30 cm. Avoid grazing if the soil is very humid (compaction)	Continuous or rotational grazing with high stocking rates to delay heading	Continuous or rotational grazing with high stocking rates
Annual grasslands (oat, barley, triticale) used for grazing	Grazing "by hours" in the presence of grain to avoid acidosis		Rotational grazing with moderate stocking rates when grass height is 20-30 cm (4-6 weeks postemergence). Residual stubble 8-10 cm. Avoid grazing if the soil is very humid (compaction)	Rotational grazing with high stocking rates to delay heading. Stop when grass height is 5-8 cm	Grazing "by hours" in presence of grain to avoid acidosis
Self-reseeding annual legumes (subterranean clovers, *T. michelianum*, annual medics)	Light grazing to eliminate the excess of stubble, without depleting the seed bank (min 1.5-2 quintals / ha)	Respect the emergence of seedlings up to 3-5 true leaves	Continuous grazing - to be preferred - or rotational grazing with moderate stocking rates keeping the height in the range 5-15 cm (avoid shading by grasses)	Continuous - to be preferred - or rotational grazing with high stocking rates to avoid shading by grasses	Avoid grazing or limit its intensity so as not to compromise the seeding, especially with the annual medics and clovers
Annual grasslands (*T. alexandrinum, T. incarnatum*) and sulla grasslands	Sulla: light grazing to eliminate excess stubble	Rotational grazing "by hours" (max. 3 hours) with moderate stocking rates starting from an entrance height of 15-20 cm	”Hourly” rotational grazing with moderate stocking rates when grass height is 20-30 cm. Avoid grazing if the soil is very humid. Leave 8-10 cm of stubble	"Hourly" rotational grazing with high stocking rates. Leave at least 6-8 cm of stubble	"Hourly" rotational grazing with moderate stocking rates
Grasslands based on biennial cichory	Light grazing to eliminate the stubble of adventitious grasses	Respect the beginning of the regrowth up to heights of 15-20 cm	“Hourly" rotational grazing with moderate stocking rates starting when grass height is similar to that of first entry. Avoid grazing if the soil is very humid. Leave 5-8 cm of leaf rosette	"Hourly" rotational grazing with high stocking rates. Leave at least 5-6 cm of leaf rosette	Rotational grazing with moderate stocking rates. Leave 5-6 cm of leaf rosette

Grazing systems in the Italian continental regions

In high-productive areas of Northern Italy, grazing plays an important role in semi-intensive forage systems under temperate climate (MIPA project, Cavallero *et al*., 1996). Traditionally in the Po Valley, livestock systems are intensive and rely on annual forage crops that offer high yields per hectare, assuring the satisfaction of animal diet requirements and allowing a high stocking rate. Nonetheless, in some areas, extensive systems and permanent or temporary grasslands are still the basis of animal feeding, especially where annual forage crops show variable yields, i.e. in sandy, shallow, acidic, or silty soils.

The meadows are typical for the farms in the area of Parmigiano Reggiano PDO cheese production, as this cheese cannot be produced with milk obtained from **dairy cows** fed with corn silage. The prevalent conservation systems for meadow forage production are haymaking and haylage. In the case of cow-calf line rearing, the choice of the proper stocking rate is the key to increase farm production. Several experiences showed that a stocking rate of max 3.2-3.4 heads ha^{-1} offered the best results in terms of animal weight and herbage quality. An example of a traditional **calf-cow line rearing** is the Piemontese cow rearing. Piemontese cows show a very low milk production and their milking is not convenient. This is why cows, after calving, graze in permanent pastures and their milk is used exclusively by their calves. After weaning, herbage availability in pastures is sufficient to assure to heifers an average daily weight gain of 0.7-0.8 kg day^{-1} during a grazing season that lasts for 180-220 days with no need of diet integrations. The cow-calf line rearing is advantageous also because the number of days between births are reduced (386 days vs. 401 with animals in barns) and the first heat is anticipated (14 vs. 17 months). Other advantages are the reduced workload for farmers (-48%) and a lower use of mechanical means.

Nonetheless, in these systems, the main drawback to a yearly grazing is the marked seasonality of herbage growth, also in irrigated planes. At the same stocking rate, grassland surfaces needed for grazing increase from 25-30% in spring to 100% in late summer.

Some data obtained with temporary grasslands showed the important role of grassland management on the behavior of forage species. A comparison between binary mixtures based on *Trifolium repens* showed that, in association with *Dactylis glomerata,* the sustainable stocking rate under rotational grazing was higher (+3%) than with *Lolium perenne*, all the other factors being equal. Nonetheless, under intensive continuous grazing, the sustainable stocking rate was higher in mixture with *L. perenne* (+5%). The botanical composition of both mixtures based on *T. repens* varied year after year, because this species tended to increase its relative presence in exclusively grazed and/or in mowed areas. To maintain a balanced mixture, the vigour of the selected cultivar of *T. repens* should be accurately chosen, as well as the nitrogen fertilization planned in spring.

Other successful mixtures used are those based on *Festuca arundinacea*. This species shows a high DM yield, high potential stocking rate, high tolerance to animal trampling and easy haymaking. Unfortunately, the presence of animal dejections on this grass reduced the amount of grazed herbage, especially in the case of continuous grazing (rejected herbage about 30%) compared to rotational grazing (rejected herbage about 20%). The presence of old rejected herbage requires its cut to rejuvenate pastures at the end of each grazing season.

Grazing systems in Italian Mediterranean regions

Beef cattle farming system

In extensive breeding, wild resources such as pastures and permanent grasslands are mainly used and complemented with cultivated forage crops (autumn-winter cereal-based temporary grasslands) to fill the gaps that occur in some time of the year (Pardini and Rossini, 1996). An example of extensive breeding can be found in the **cow-calf line rearing** used with the Maremmana cow breed. This breed is rustic and frugal, resistant to diseases and harsh environments and is able to use poor fodder. A stocking rate of 1.3 LSU is used in the most favorable production conditions. Grazing management is intensive continuous grazing. The farming system is planned for the exclusion of animals from grazing on a portion of the farm only during spring season, when forage stocks need to be created (e.g. 1st April - 15-30th June). A part of forage stocks is used as standing hay for deferred grazing in summer. The remaining portion of stocks are mowed at the end of May and the hay is used to fill the late autumn and winter forage gaps. This farming system allows to meet the animal diet requirements all year round, requiring limited supplies of forage stocks coming from pastures or temporary grasslands, produced on farm. However, in difficult years, when spring forage production is low, the use of extra-farm stocks is possibly needed. In some forage systems, a portion of the natural pasture is replaced by a pure stand meadow of lucerne or a pasture-meadow based on mixtures of perennial grasses (*F. arundinacea* and *D. glomerata*) and legumes (*T. pratense* and *T. repens*).

Dairy sheep farming systems

Two main farming systems are commonly adopted with sheep. The first one, the agro-silvo-pastoral system, is based on wooded grasslands, widespread in hilly and mountain areas. The second one is a mixed cereal-animal system, connected to extensive widespread agriculture in the lowland areas and low hilly areas. Nevertheless, a wide range of intermediate situations exists between these two systems, which gives rise to extremely variable and complex types. In practice, each farm is characterized by its own forage system where the grasslands play a different role.

The agro-silvo-pastoral system is mainly based on the use of natural or semi-natural pastures and sowed pastures with or without fertilization, and a variable proportion of the autumn-winter temporary grasslands. The main limitation of this system is the difficulty to match the forage availability coming from the pastures with the animal requirements. In fact, while grass production is concentrated in spring, the highest sheep feed needs are reached in autumn and in winter at the end of pregnancy and the start of lactation. Moreover, the forage productivity of this system is very unpredictable in quantitative and qualitative terms.

Feed integration is used during these two critical periods. At the beginning of autumn, when the first rains occur, the flock is confined to a small plot to allow the re-establishment of pastures, as well as during winter, when the available forage production in pastures is poor. Usually, a relatively high seasonal stocking rate (10-20 sheep ha^{-1}) is used, especially if there is the need to reserve areas for mowing or standing hay. Sheep are moved to a new plot (pasture or temporary grassland) on the basis of sward production, but more often on the basis of flock milk production: when it starts to decrease, the flock is moved. Pasture grazing covers between 60 and 85% of the total animal requirements.

In **the mixed cereal-animal farming system**, winter cereals and temporary grasslands, in pure stand or in mixture with annual legumes, represent the fundamental resource while the contribution of the pasture is restricted to the areas that cannot be mechanized. They are grazed both as green forage and as stubble. In this system type, crop rotation is based on an irregular sequence (from 2 to 4 years) of different cereal crops, such as durum wheat, barley and oat, and pasture fallow. Cereal crops are largely used because they increase the flexibility of this system, which is well suited to the variable Mediterranean climate conditions. In years with adverse meteorological conditions, cereals are only used for grazing and not for haymaking or grain production. In more favourable years, cereals (especially local ecotypes of barley and oat) can provide high-quality DM biomass for grazing during winter (tillering stage) and once grazing is suspended, usually in mid-February, they are used for grain production.
In spring, the flock is confined to a portion of cultivated lands and pastures, where the high grazing pressure is sustained by the rapid spring growth rates of grass. The rest of arable lands is preserved to produce grain and / or hay. One of the main limitations of the mixed cereal-animal farming system is represented by the establishment of cereals, which is strongly conditioned by the autumn rainfall which can cause long delays due to a prolonged summer drought or, on opposite, to waterlogging. The concentration of production, linked to the typical Mediterranean conditions, makes it difficult to identify simplified solutions and, on the contrary, requires a wider diversification of the resources within the forage system. The integration of several fodder sources is essential to achieve satisfactory food quality and hence, to make the farming system more efficient, flexible and self-sufficient. To this regard, encouraging results have been obtained with the introduction of the annual self-reseeding pasture species and the perennial species for meadow- pasture, mentioned in the next paragraph.

Final remarks about the key aspects for adaptation to climate change of Italian Mediterranean grasslands

Several negative effects are expected on Mediterranean grasslands: increased failures at establishment, decreased grassland productivity and long-term persistence, shortening of the grazing season unless the grassland is irrigated; reductions in desirable grassland species is likely to occur, in favour of species with low palatability and broad ecological niches, due to reduced competition for water and nutrients (Del Prado *et al*., 2014). In any case, to prevent possible negative effects caused by climate change, increasing grasslands resilience and improving forage production and rehabilitating permanent grasslands are compulsory. The main key-factors that can increase resilience and adaptability and could be considered also as mitigation strategies from climate change are listed below:

- *Sowing annual and perennial species with high summer drought survival.* The predicted changes in rainfall distribution, consisting of relatively lower and more variable autumn rainfall and a shorter spring, mean that some or all of the following traits are needed in annual legumes: (i) earlier maturity for reliable seed set in shorter growing seasons; (ii) more delayed softening of hard seeds to reduce seedling losses from more prevalent false breaks; (iii) greater hardseededness to compensate grassland survival for more frequent seasons of little or no seed set; and (iv) a less determinate flowering habit to take advantage of longer growing seasons when they occur. In perennial species, desired characteristics include dormancy or low growth during the drought period, survival across drought periods, and high water use efficiency during the growing season.

- *Increasing legumes utilization.* The biological N-fixing activity of legumes contribute to the soil N-enrichment, and this feature could contribute to farm sustainability. The several species have a different efficiency in fixing atmospheric nitrogen, e.g. up to 150-190 kg N ha^{-1} $year^{-1}$ in sulla and lucerne. In the past, the traditional annual legumes used for grassland rehabilitation were *Trifolium* spp. and *Medicago* spp. Nowadays, other species belonging to the genera *Ornithopus*, *Vicia*, *Melilotus* and *Biserrula* are available on the seed market. Among perennial legumes, lucerne is the most appreciated species in many farming systems but some limitations to its use arise under rainfed conditions, where lucerne shows a low forage production, limited persistence and scarce tolerance to grazing, requiring the selection of suitable cultivars. Other perennial legumes such as sulla and sainfoin, are summer-dormant and already used for both their contribution in stabilizing grassland production and forage quality and their content of condensed tannins, which can promote amino-acid absorption in the intestine and also reduce the load of gastro-intestinal parasites.

- *Promoting the use of grassland mixtures.* The potential agronomic, environmental and economic advantages of sowing mixtures of forage species and cultivars are widely recognised, especially when mixtures are based on well adapted genotypes. Porqueddu and Maltoni (2007) and Maltoni *et al*. (2007) showed that grass-legume mixtures belonging to different functional groups, achieved higher DM yields, better seasonal forage distribution, better weed control and higher forage quality than pure stands of each species. More persistent grasslands could be also obtained using mixtures of summer-dormant and summer-active perennial species and varieties able to exploit available soil moisture throughout the year (Norton *et al*., 2012).

- *Benchmarking grassland typologies to improve the management of grassland resources.* The knowledge of grassland typology is needed to adopt the best management practices; in fact, the differences in vegetation and phytosociological associations are still relevant in Mediterranean areas. Agronomic typologies based on the forage value of dominant or reference species, or synthetic indexes were designed in different countries and recently, a first attempt to synthesize and homogenise grassland typologies at plot, farm and regional level in the different EU states was done by Peeters (2015). With regards to grazing, the extent and intensity of grazing differs among vegetation types and geographical locations. Among methods utilized by technicians and extension services for grassland typology assessment, the pasture-type approach, based on the determination of the Pastoral Value (PV) of grasslands, has been applied in several Mediterranean, Alpine and Apennine areas, with the main goal of characterizing pasture vegetation and its potential carrying capacity (Argenti and Lombardi, 2012).

References Chapter 7 - Italy

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Shared Innovation Space for Sustainable Productivity of Grasslands in Europe

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Deliverable 5.3. Specific grassland syllabus and power point presentations available for young farmers and advisors

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Submission date: 28 February 2019

Inno4Grass – Education material on practical grassland management

Country grassland characteristics Inno4Grass

Table of contents

This powerpoint consist of contributions of several countries.
The material have been provided by the partners of different countries

(You can use the hyperlink to go to a specific country)

Sweden

Characteristics of grassland production and utilisation in Sweden

Nilla Nilsdotter-Linde
Eva Spörndly
Rolf Spörndly

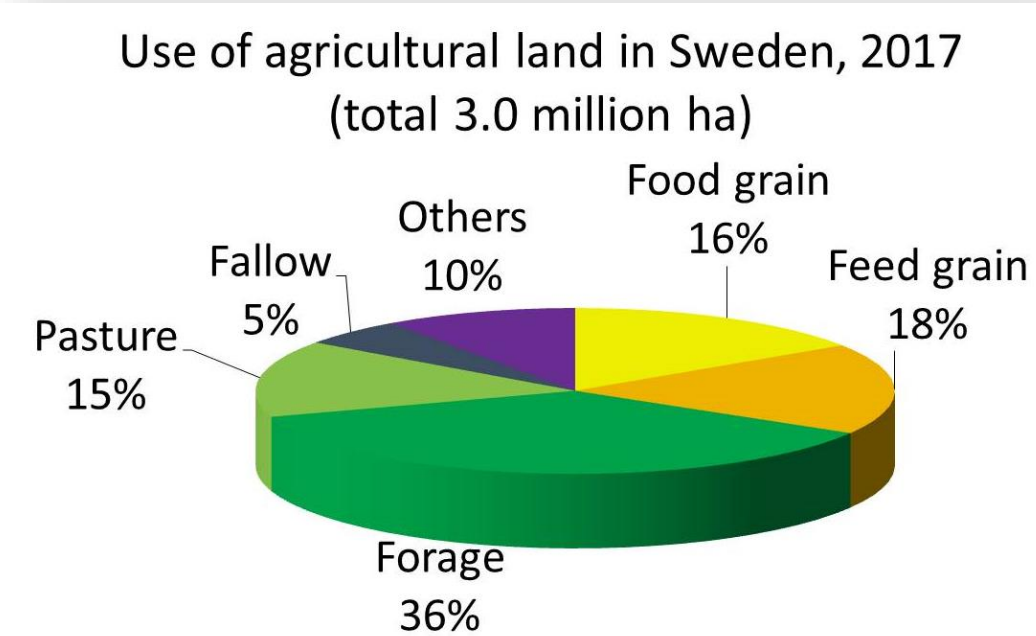

Photo: Timbro.se


Photo: Nilla Nilsdotter-Linde


Photo: Rolf Spörndly


Photo: Rolf Spörndly

Land use in Sweden



(Swedish Board of Agriculture, 2018)

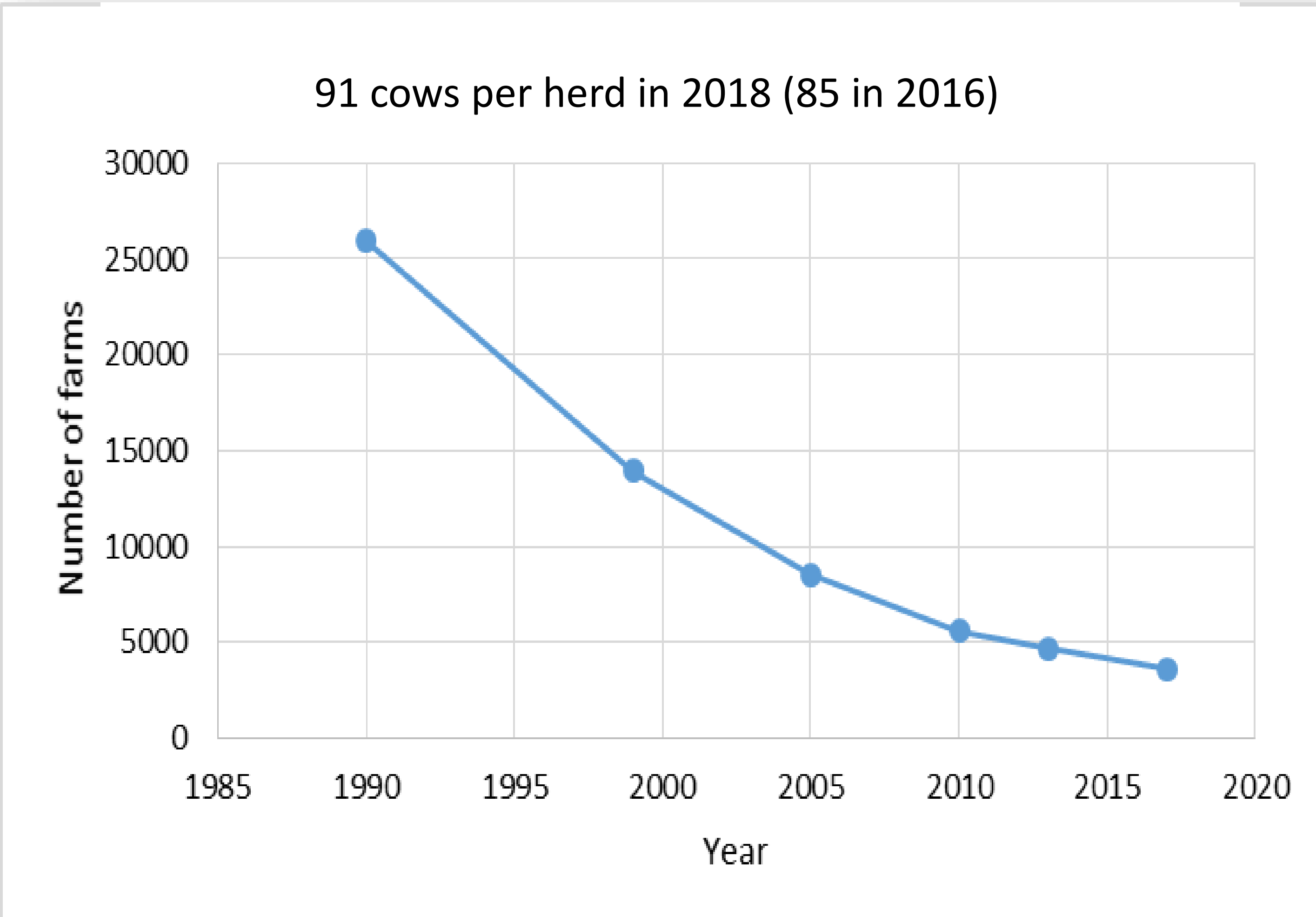
Sweden is a vast country of forests and mountains…..

Total Sweden	**45 mil. ha**
with:	
- Forest	- 24 mil. ha
- Heathland/peat	- 7 mil. ha
- Mountains/hills	- 5 mil. ha
- Water	- 4 mil. ha
- Agriculture	- 3 mil. ha
- Built/cities/roads	- 2 mil. ha

19% of agricultural land is in organic production

~75% of agricultural land is used for feed production

Number of dairy farms in Sweden, 1990-2017



(Swedish Board of Agriculture, 2018)

The typical ration for the high-yielding dairy cow

- 11-13 kg DM silage. Grass/clover, pre-wilted
- 7-9 kg rolled cereals. Barley, oats, wheat
- 5-7 kg protein concentrates
- Rape seed meal is the most common protein feed, followed by soy bean meal. Palm cake and sugar beet pulp are important ingredients in the concentrate

Year	Feed ration	
1975	7 kg hay + 10 kg concentrate* (shift from hay to silage)	
1982	11 kg DM silage + 10 kg concentrate (75/10/15)*	
1986	9 kg DM silage + 13 kg concentrate (60/20/20)*	
1994	7 kg DM silage + 16 kg concentrate (50/30/20)*	
2005	9 kg DM silage + 16 kg concentrate (50/30/20)*	
2015	12 kg DM silage + 15 kg concentrate (50/30/20)*	

* = grain/sugar beet pulp/oil seed cake (%).

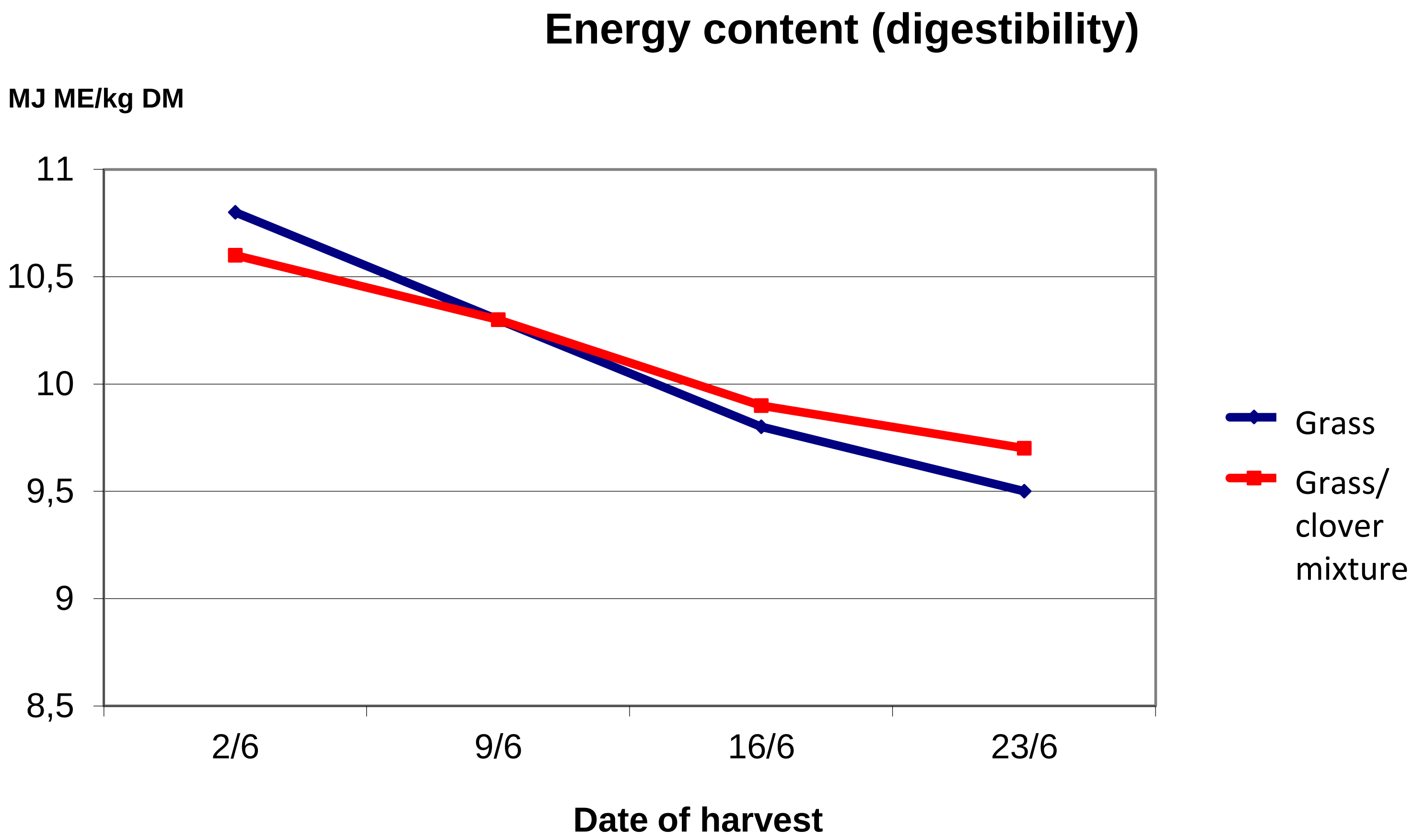
Typical milk yield for the high-yielding dairy cow

- 11-13 kg DM silage. Grass/clover, pre-wilted
- 7-9 kg rolled cereals. Barley, oats, wheat
- 5-7 kg protein concentrates
- Rape seed meal is the most common protein feed, followed by soy bean meal. Palm cake and sugar beet pulp are important ingredients in the concentrate

Year	Feed ration	Milk yield per cow/year (kg)
1975	7 kg hay + 10 kg concentrate* (shift from hay to silage)	5500
1982	11 kg DM silage + 10 kg concentrate (75/10/15)*	6200
1986	9 kg DM silage + 13 kg concentrate (60/20/20)*	6700
1994	7 kg DM silage + 16 kg concentrate (50/30/20)*	7600
2005	9 kg DM silage + 16 kg concentrate (50/30/20)*	8500
2015	12 kg DM silage + 15 kg concentrate (50/30/20)*	10 000

* = grain/sugar beet pulp/oil seed cake (%).

High intake is totally dependent on high-quality forage – grass/clover dominates



Date of harvest is more important in pure grass leys than in mixed leys.

Date of harvest has a 'turbo' effect on forage quality due to higher intake of early harvested forage

	Late harvest	*Early harvest*	
5.5 MJ NEL_{20}/kg DM	10.0 MJ/kg DM	11.5 MJ/kg DM	6.7 MJ NEL_{20}/kg DM
Silage intake	10 kg DM/day	12 kg DM/day	Silage intake
	↓	↓	
55 MJ NEL_{20}/day	100 MJ/day	138 MJ/day	80.4 MJ NEL_{20}/day
	=	=	
	7 L milk	14 L milk	

Excellent silage for dairy cows

- Good nutritional value
  - Energy — 11-11.5 MJ/kg DM
  - Crude protein — 130-160 g/kg DM
  - DM — 30-35%
  - Fibre — 450-550 g NDF/kg DM
- Palatable – high sugar content
- Good hygiene quality

Forage has to be preserved for an 8-month winter period. In the past, hay-making was the only available method

1970s and 1980s – transition from hay to silage

- Larger farms
- Less weather-dependent
- Lower nutrient losses
- Higher milk production

After 1980, silage making took over and is now the dominant harvesting method

Daily feed data intake and animal performance data. Early cut at booting stage and late cut 10 days later

	Early cut hay	Early cut silage	Late cut silage
Forage intake, kg DM day^{-1}	8.7^{a}	8.4^{b}	8.5^{b}
Concentrate intake, kg DM day^{-1}	8.1	8.4	8.6
Energy intake, MJ day^{-1}	197	199	194
Milk production, kg day^{-1}	26.1^{a}	27.4^{b}	26.2^{a}
Milk fat content, %	4.56	4.65	4.57
Fat-corrected milk, kg ECM day^{-1}	28.6^{a}	30.5^{b}	28.3^{a}

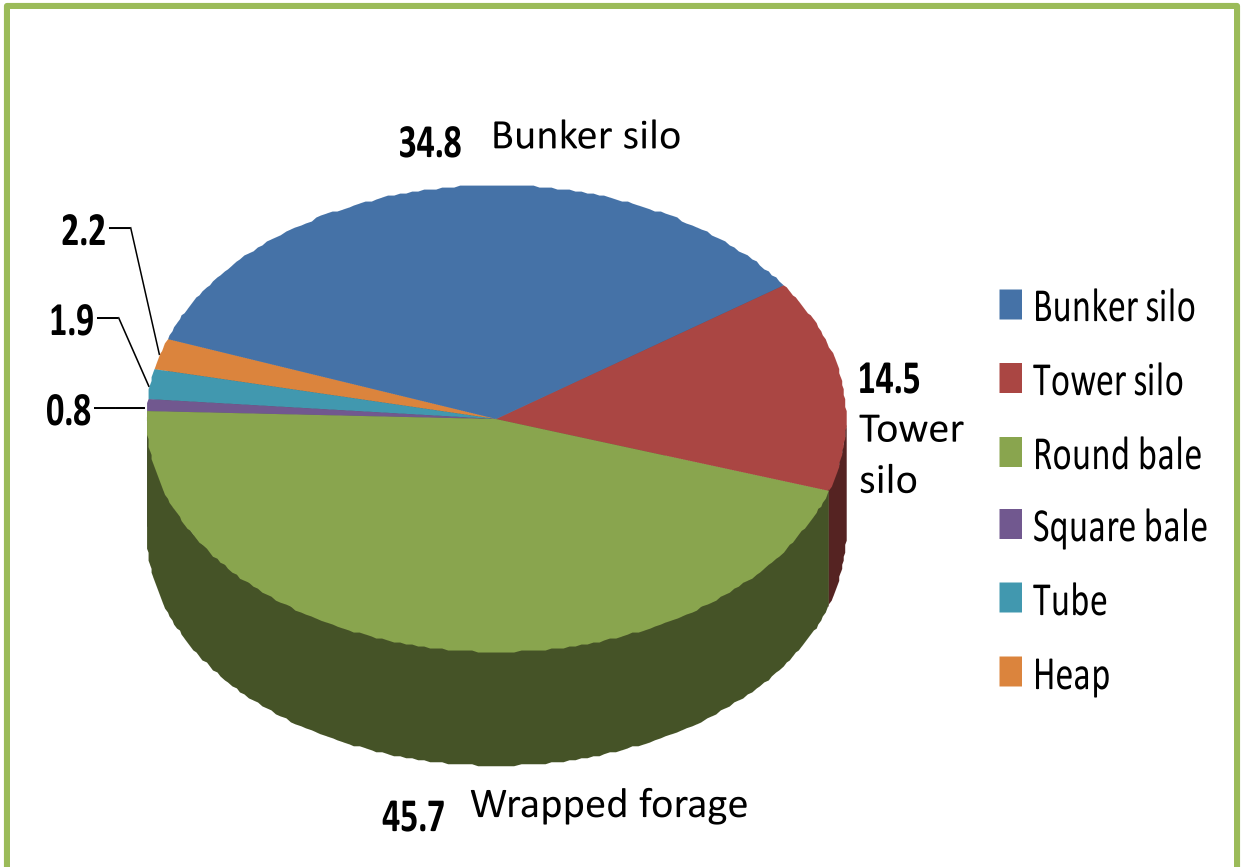
- Three-year ley fertilised with 89 kg N, species timothy, meadow fescue and red clover.
- Hay wilted to 60% in the field and to 87% DM in indoor drying.
- Silage direct-cut, 26% DM.
- Forage fed restricted, concentrate according to milk yield.
- Lactation week 2-10, year 1.

The key to higher milk production with silage is the possibility to cut it early!

(From Bertilsson, 1983)

Silo systems in Sweden

Expressed as % of total quantity of silage



(Pettersson *et al.*, 2009)

Silo systems

- 1980s – wooden tower silos
- 1990s – steel tower silos
- 2000s – bunker silos and round bales

In Sweden, wrapping is the most common silo system for silage from grassland

Wrapped silage is used on small and medium-sized dairy farms, as a complement on large dairy farms, for beef cattle and also for horses in Sweden

Livestock in Sweden	Number
Dairy cows	322 000
Beef cows	207 000
Young stock	499 000
Calves	472 000
Total cattle	1 500 000
Ewes, ram	301 000
Lamb	305 000
Total sheep	606 000
Total horses	355 000

(Swedish Board of Agriculture, 2018)


Photo: Rolf Spörndly


Photo: Eva Spörndly

Note: There are more horses than dairy cows in Sweden!

Recent research on dry matter losses from different silo systems

Materials and Methods

- 12 bunker silos, 6 tube silos, 3 tower silos and 60 round bales
- Located on 12 different farms
- Silo balances (all in – all out) recorded
- Large silos: All loads going in were weighed and sampled, all loads going out were weighed but sampled three times per week
- Round bales: All bales were weighed before and after storage and every second bale was sampled

(Spörndly, 2018)

Recent research indicates lower losses from wrapped forage than from large silos and surprising results about filling speed of bunker silos

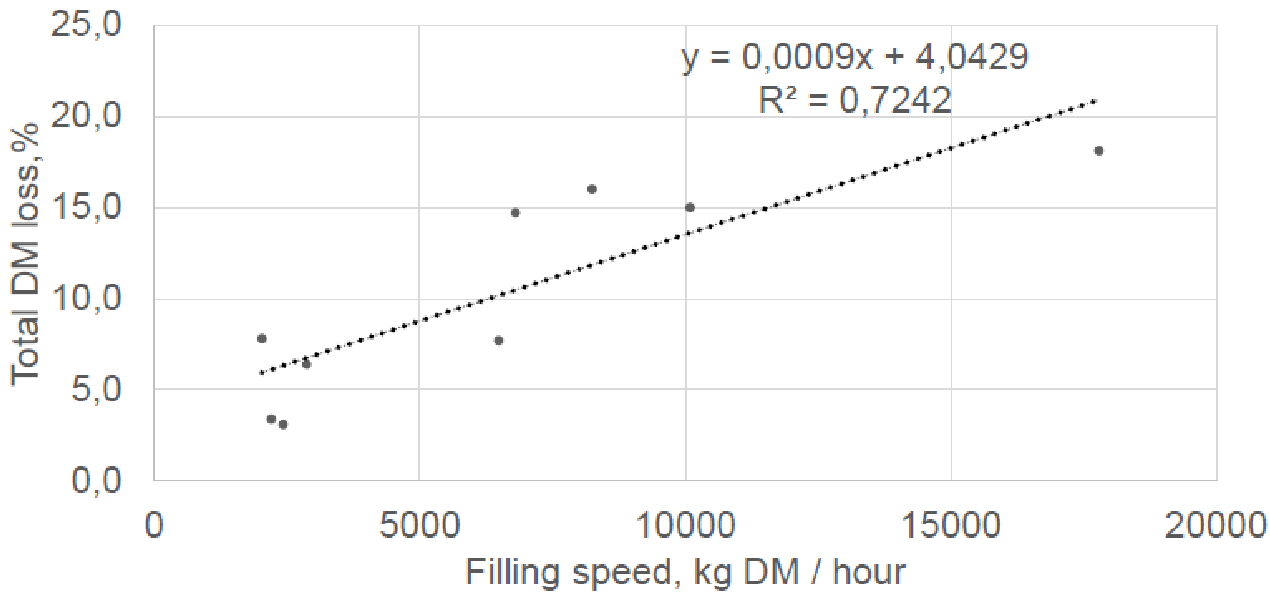


Figure 1 Total DM loss as a function of filling speed in 9 bunker silos. Hours are counted from start to end of filling, including night time hours.

	DM loss, %	
	Total	Discarded
Bunker	14.1[a] (8.7)	3.4 (4.4)
Tube	11.5[b] (9.4)	1.9 (3.8)
Tower	23.4[ab] (2.2)	0.1 (0.1)
Round bales	1.1[c] (0.4)	0.0 (0.0)

(Spörndly, 2018)

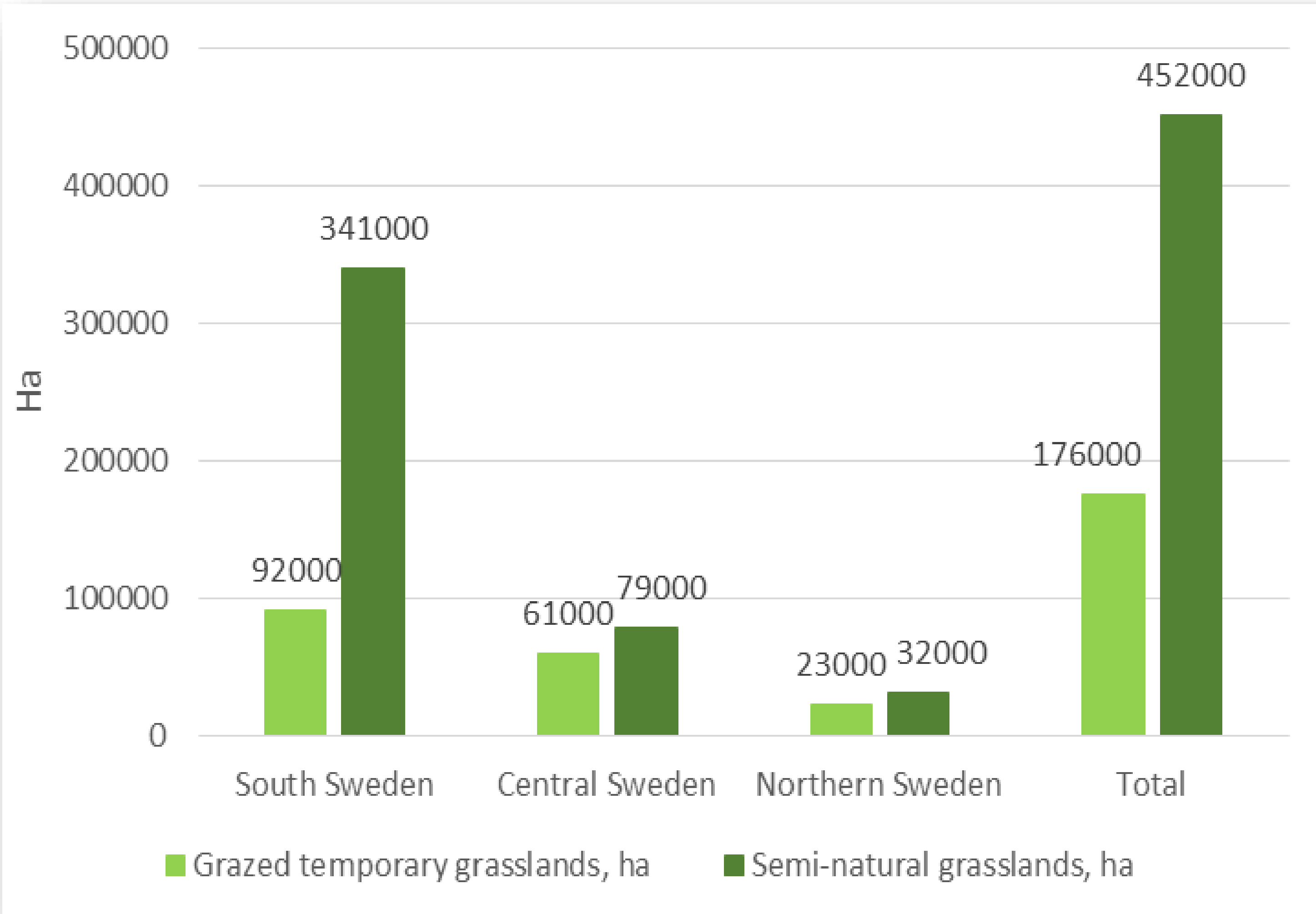
Dry matter losses from different silo systems

Conclusions

- Considerably lower silage DM losses in round bale silage than in large silos (bunker, tube, tower)
- Discarded silage losses low (1-4%), but invisible DM losses high (10-20%) in large silos
- Great variation in DM losses between farms for each large silo system
- Slow filling and careful compaction are key to low losses in bunker silos

(Spörndly, 2018)

Area of semi-natural grassland and grazed temporary grassland in Sweden, 2017 (ha)



(Swedish Board of Agriculture, 2017)

Temporary grassland is best suited for dairy cows (e.g. Swedish Red breed and Swedish Holstein) and heavy beef breeds (e.g. Charolais)


Photo: Eva Spörndly

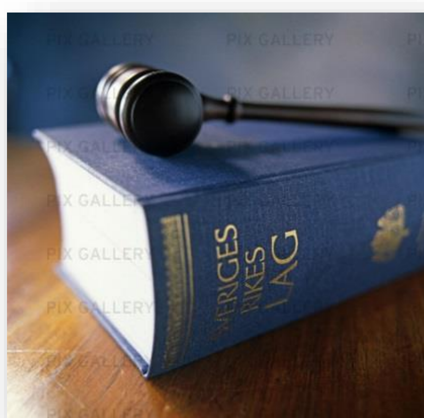

Photo: Eva Spörndly

Semi-natural permanent pastures in Sweden are best suited for lighter beef breeds, recruitment heifers, horses and sheep

Swedish legislation requires pasturing during summer

- Dairy cows must have access to pasture for at least 6 h/day
- Other cattle[1] and sheep must be kept on pasture for 24 h/day
  Exceptions are bulls and young calves (below 6 months)
- The required length of grazing period is 60 days in northern Sweden, 120 days in southern Sweden

[1]Suckler cows and their calves, recruitment heifers, dry cows etc.



(Swedish Board of Agriculture, 2016)

Grazing systems and pasture use
1. Dairy cows

Dairy cows in conventional production

- The law requires at least 6 h pasture access/day
- In 2018, Sweden's largest dairy company introduced an extra payment for +25% more grazing on pasture than required by law. Many farmers have signed up for the system
- Large amounts of supplementary concentrates (50% of DM intake)
- Supplementary silage is often provided
- Mainly grazing temporary grass swards with high digestibility

Dairy cows in organic production

- Must be on pasture for longer than 12 h/day
- Daily pasture intake must be at least 6 kg DM daily
- Mainly grazing temporary grass swards with high digestibility

(KRAV, 2018)

Organic production in Sweden

Organic production	Proportion of total agricultural area or animal stock (%)
Total acreage	19.1
Cereal grain (wheat, barley, oats, rye, triticale)	9.5
Forage (legumes/grass, green fodder, ploughed)	22.1
Semi-natural pasture	24.6
Dairy cows	16.4
Beef cows	33.7
Sheep	20.9
Pigs	2.3
Laying hens	17.0
Broilers	1.9

- Increasing in all sectors
- Particularly pronounced in forage and cattle production

(Swedish Board of Agriculture, 2018)

Automatic milking (AM) and grazing

- Approximately one-third of milk in Sweden is produced in AM systems
- Conventional (non-organic) farms with AM often graze mainly to fulfil the legal requirement, and provide exercise pasture combined with substantial amounts of concentrates and silage indoors
- AM systems are also common in organic production, but with at least 6 kg DM from pasture/day in the diet
- The EU research project AUTOGRASSMILK provides more information about AM and grazing in Sweden and other European countries (https://autograssmilk.dk/)

Grazing systems and pasture use
2. Sheep and cattle for growth and meat production

Animals that are required to graze 24 h daily (cattle and sheep):

- Graze to a large extent on permanent semi-natural pastures
- Swedish farmers receive subsidies for grazing permanent semi-natural pastures, as these pasture areas have high biodiversity

Many semi-natural pastures are important for threatened species in Sweden: flowers, insects, birds etc.

Semi-natural pastures are more species-diverse than temporary grassland

Vegetation type in semi-natural Swedish pastures	Herbage mass, kg DM/ha and season	Metabolisable energy, average over season, MJ/kg DM
Dry	1800	9.5
Mesic	3000	9.7
Wet	4400	8.6
Shaded	1400	9.0

(Spörndly and Glimskär, 2018)

Cattle, horses and sheep grazing on semi-natural permanent pastures

% of acreage, sites and number of grazing animals. N = 219 sites, with an average size of 14 ha

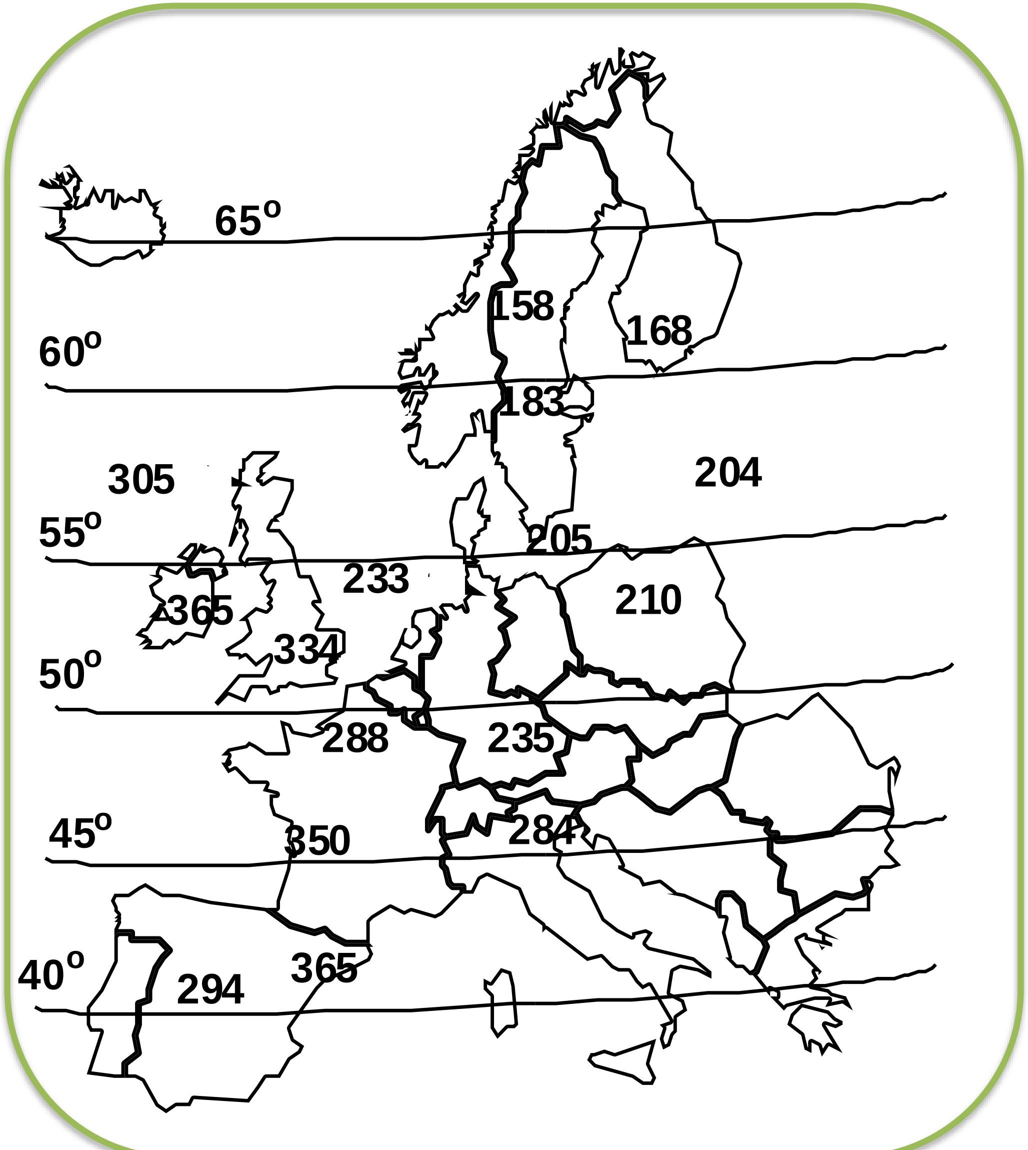
	% of acreage	% of grazing sites	% of grazing animals
Cattle	68	64	66
Horses	8	18	5.5
Sheep	9	11	28.5
Mixed[1] (mainly cattle & sheep)	15	7	

[1]In this category there were two large sites (242 and 112 ha) that were grazed by cattle and sheep.

(Spörndly and Glimskär, 2018)


Photo: Eva Spörndly

Length of the growing season in Europe



Length of the growing season, days >5°C

These conditions result in some species being better adapted….

The following species are among the best adapted in grasslands in Sweden

Timothy
(Phleum pratense)

Meadow fescue
(Festuca pratensis)

Red clover
(Trifolium pratense)

White clover
(*Trifolium repens)*

Photos: Nilla Nilsdotter-Linde

In Sweden, short-term leys as part of arable crop rotations are the main forage crop, unlike the perennial forage swards farther south in Europe

- The traditional mixture for **hay and silage** is red clover, timothy and meadow fescue
- The traditional mixture for **grazing** is white clover, meadow fescue, perennial ryegrass and smooth-stalked meadow grass

DM yield is lower but organic matter digestibility (OMD) is higher with three cuts compared with two cuts a year in swards with grass (timothy and meadow fescue) and in swards with grass and clover (100 kg N per ha)

(Kornher, 1982)

In the 1980s, more erect varieties of white clover were introduced and tested for potential inclusion in mixed, short-term leys

1.	**Seed mixture**
A.	Red clover (5) + Timothy (10) + Meadow fescue (7)
B.	White clover (5) + Timothy (10) + Meadow fescue (7)
C.	White clover (5) + Timothy (10) + Meadow fescue (7) + Smooth-stalked meadow grass (3)
2.	**Fertilisation strategy (N)**
N0.	0 kg/ha
N1.	100 kg/ha
N2.	200 kg/ha
3.	**Cutting strategy**
S1.	3 cuts/year (~13/6, 25/7, 5/9)
S2.	3 cuts/year (~6/6, 18/7, 5/9)
S3.	4 cuts/year (~6/6, 4/7, 1/8, 5/9)

(Svanäng and Frankow-Lindberg, 1994)

White clover compared with red clover in mixed, short-term leys

N level	Trifolium ssp.	1st year	2nd year	3rd year	4th year
0 kg N	Red clover	8 430	7 647	6 363	5 491
	White clover	7 724	8 085	7 441	7 765
100 kg N	Red clover	9 597	9 359	7 795	7 141
	White clover	9 123	9 534	8 169	8 152
200 kg N	Red clover	10 409	10 202	8 569	8 213
	White clover	9 920	10 246	8 619	8 565

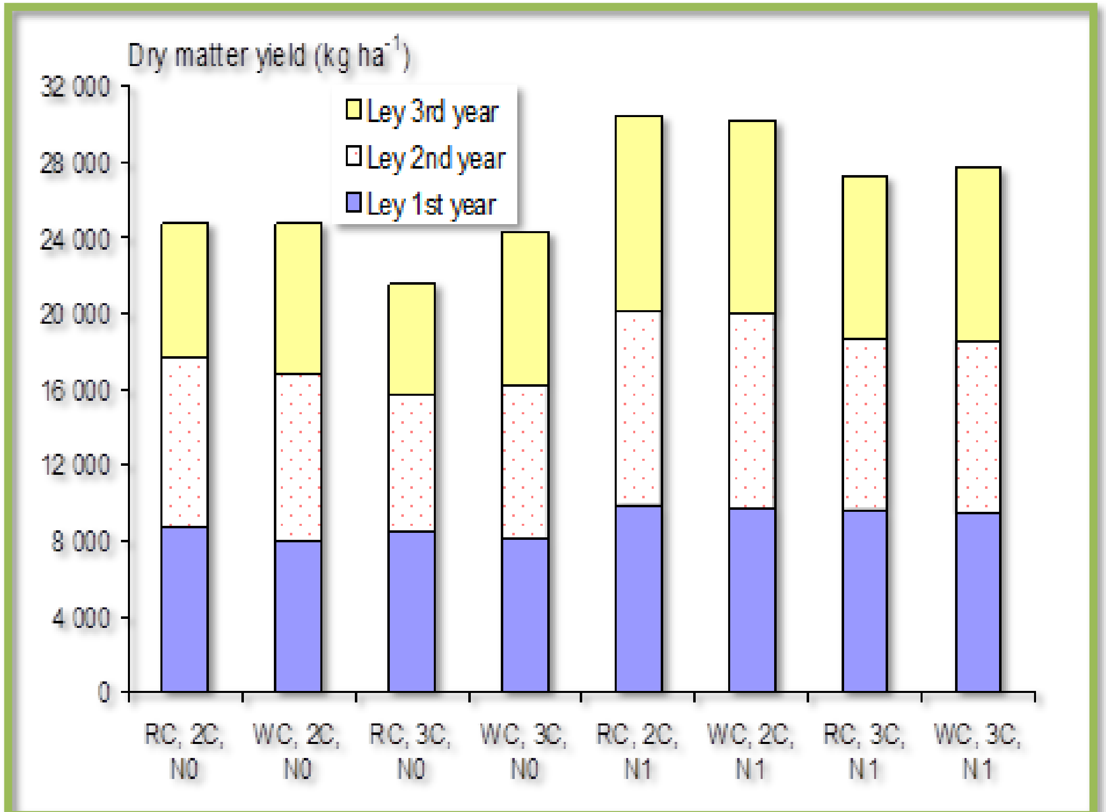
Photo: Ann-Charlotte Wallenhammar

- On average for different fertilising and cutting regimes (3 or 4 cuts/year), white clover/grass mixtures were found to be better than red clover/grass mixtures
- Red clover yielded more in young leys, but white clover persisted for longer

Root rot is the major obstacle to more long-lived red clover swards

(Svanäng and Frankow-Lindberg, 1994)

Can white clover be recommended in areas with less intense production due to farming tradition and climate conditions?



- Two cuts gave higher total yields than three
- Digestible energy was lower with two cuts than with three
- On average, the difference between red and white clover yield was small, but in the third year unfertilised white clover yielded more than unfertilised red clover

RC = red clover, WC = white clover

2C = 2 cuts/year, 3C = 3 cuts/year

N0 = 0 kg N/ha, N1 = 100 kg N/ha

Grasses = timothy and meadow fescue

N = 11

(Nilsdotter-Linde *et al.*, 2002)

With the arrival of intensive harvesting systems and more white clover in silage leys, ryegrasses have become more interesting

- These species are not as prevalent in Scandinavia as farther south because their longevity is more or less restricted depending on climate conditions, with winter kill always a threat

- Perennial ryegrass is only recommended in the southern third of Sweden


Photo: Nilla Nilsdotter-Linde

Late autumn cutting was tested as a way to reduce damage caused by e.g. snow mould (*Fusarium nivale*) and thus improve winter survival in perennial ryegrass

Effect of autumn cutting management on subsequent dry matter (DM) yield in perennial ryegrass (mean different varieties)

	Yield, 10^3 kg DM/ha					
	2nd year					3rd year
Treatment	1st cut	2nd cut	3rd cut	Total yield		1st cut
With late autumn cut	3.31	1.94	2.56	7.81		2.40
Without late autumn cut	4.46	1.92	2.71	9.11		3.25
Significance	**	NS	NS	*		**

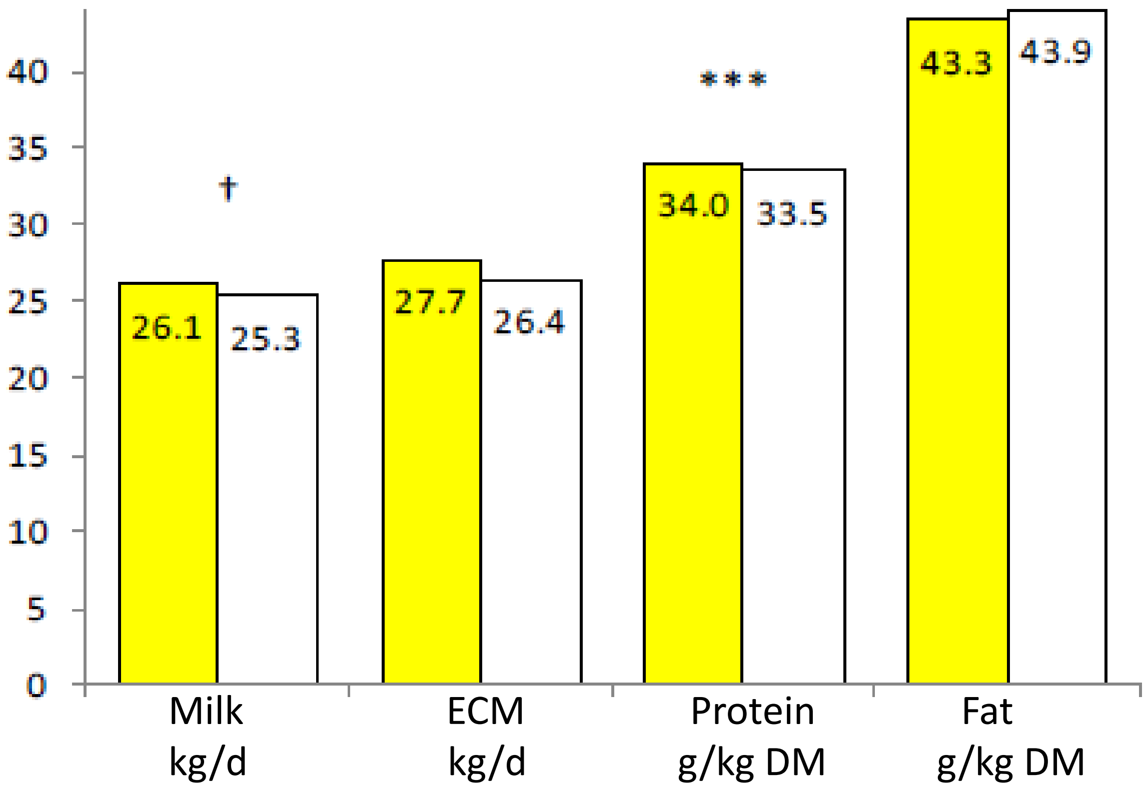
- Cutting as late as possible before cessation of growth significantly reduced the following spring yield by about 25% in both the second and third year
- No residual effect of late autumn cutting on subsequent cuts
- Ryegrass still has problems with winter kill and remains a minority grass in Swedish leys

(Halling, 1994)

Trends for the future

- There is now renewed interest in producing home-grown protein to replace imported protein
- Deeper knowledge about cultivation of grasses and legumes that are more tolerant to dry and/or wet conditions is important, to better cope with future climate change
- There is increasing interest in species with special qualities, e.g. water-soluble carbohydrates and condensed tannins
- Studies on birdsfoot trefoil, a minor forage legume containing condensed tannins, confirm that it can withstand Swedish climate conditions

Milk yield and milk composition for dairy cows fed birdsfoot trefoil-ryegrass silage or white clover-ryegrass silage in changeover experiments in two consecutive years (N = 76)



Birdsfoot trefoil

White clover

***$P < 0.001$; †$P < 0.10$

(Eriksson *et al.*, 2012)

A tendency for higher milk yield and somewhat higher milk protein content resulted in higher protein yield with the birdsfoot trefoil-ryegrass silage, but ECM yield did not differ significantly between the diets.

How do the new conditions influence seed selection?

- More frequent cutting - white clover and perennial ryegrass
- Better winter hardiness - white clover, timothy and tall fescue
- Better fibre quality - timothy and lucerne
- New protein sources - legumes incl. birdsfoot trefoil

Resulting in the following trends in seed mixtures:

- Timothy ↗
- Meadow fescue ↘
- Perennial ryegrass ↘
- Tall fescue ↗
- Red clover ↘
- White clover ↗
- Lucerne ↗

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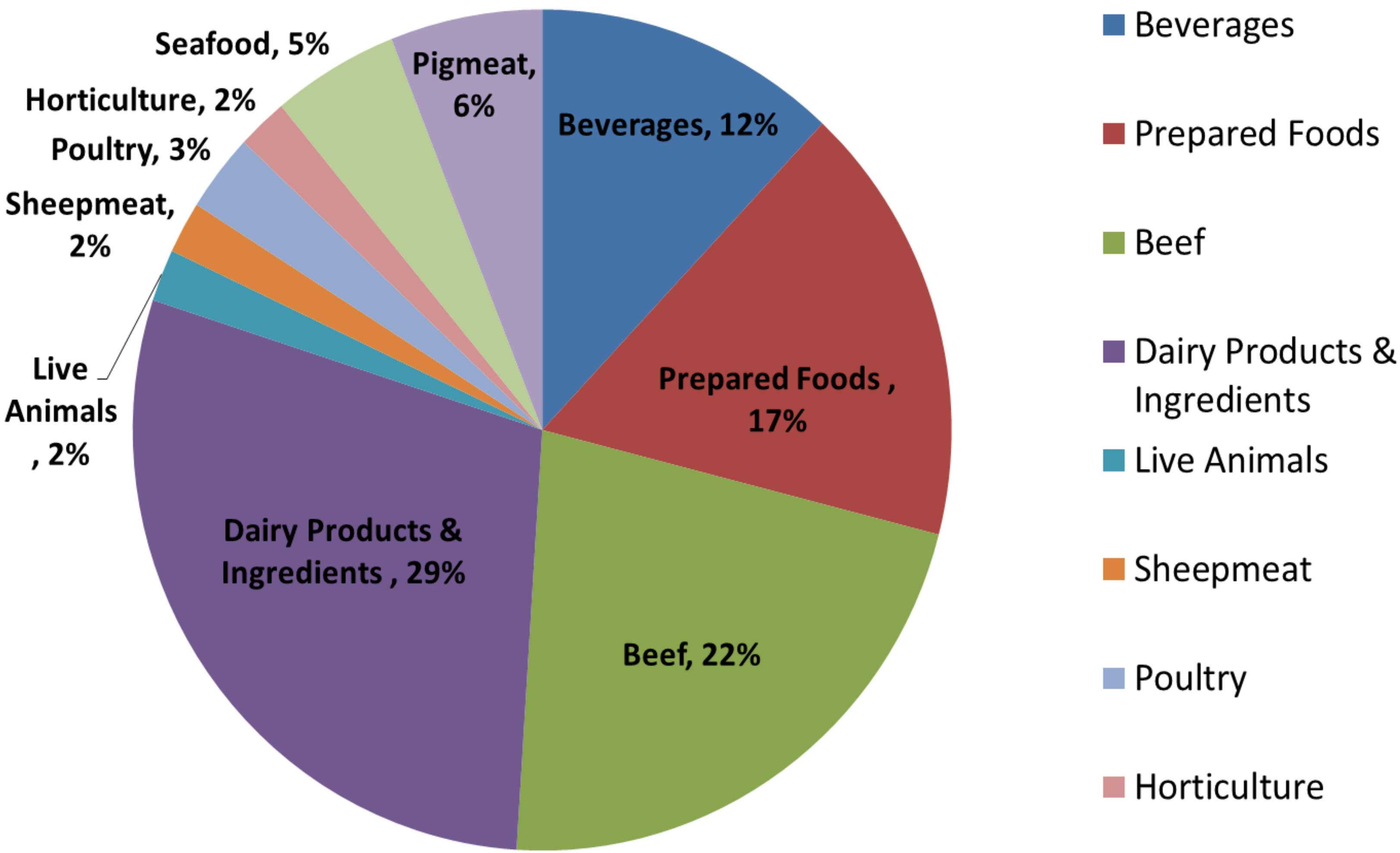
Ireland

Grassland in Ireland

-

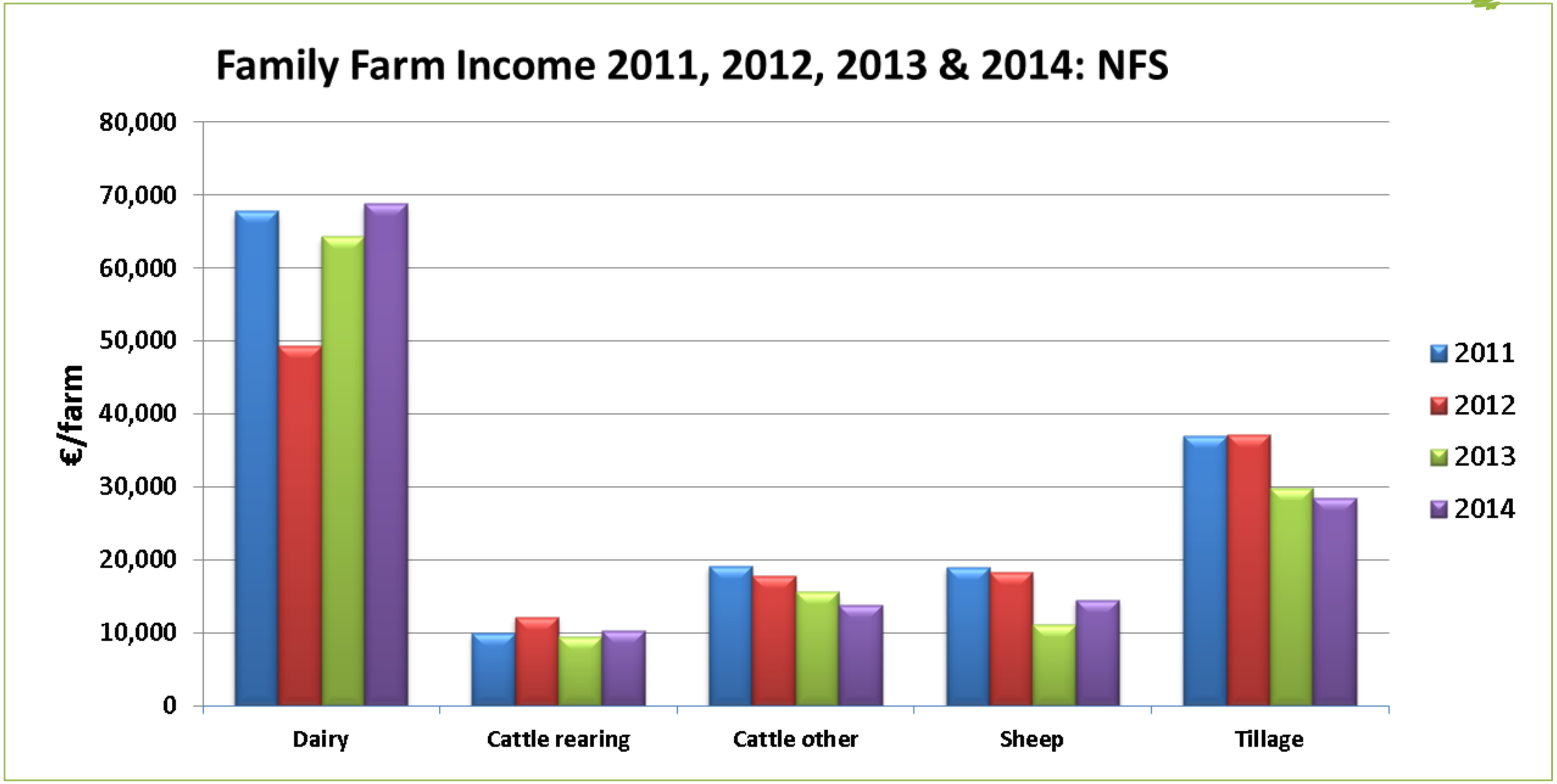
Michael O'Donovan
& Fergus Bogue

Total Agri-food Exports €10.45bn 2014



Source : Bord Bia

The Efficiency of Agricultural Production In Ireland



Key Technologies

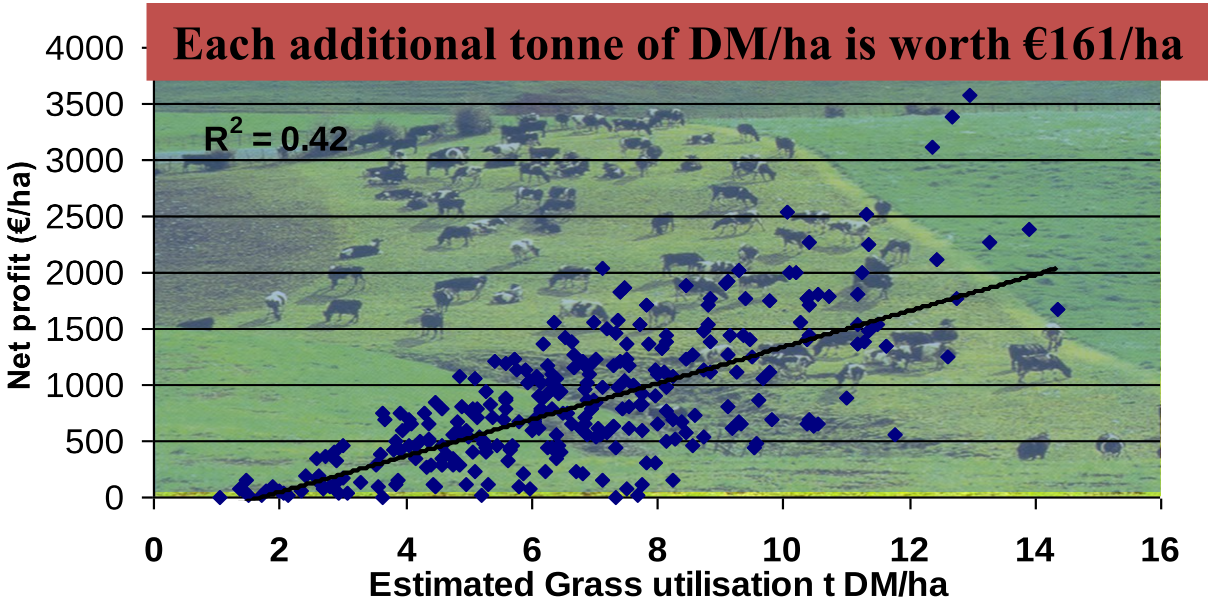
- Animal breeding – generating highly profitable animals for grazing system
- Grass production & utilisation: soil fertility, grazing management; grass breeding
- Farming system: Resilient low cost grass-based

Structure of Irish Dairy Industry

- Number of dairy farmers - 18,000
- 2015: Average herd size-82 cows, farm size-63 ha, producing 350,000 litres
- System : Predominately season spring calving pasture pasture-based system
- Total of 19 milk processors-82% of milk processed by 6-major processors
- 2020: 85 cows /herd producing 425,000 liters; 1.4 million dairy cows; 5500 liters/cow 3.55% P & 4.20% F

Stocking rate and Grass Utilisation

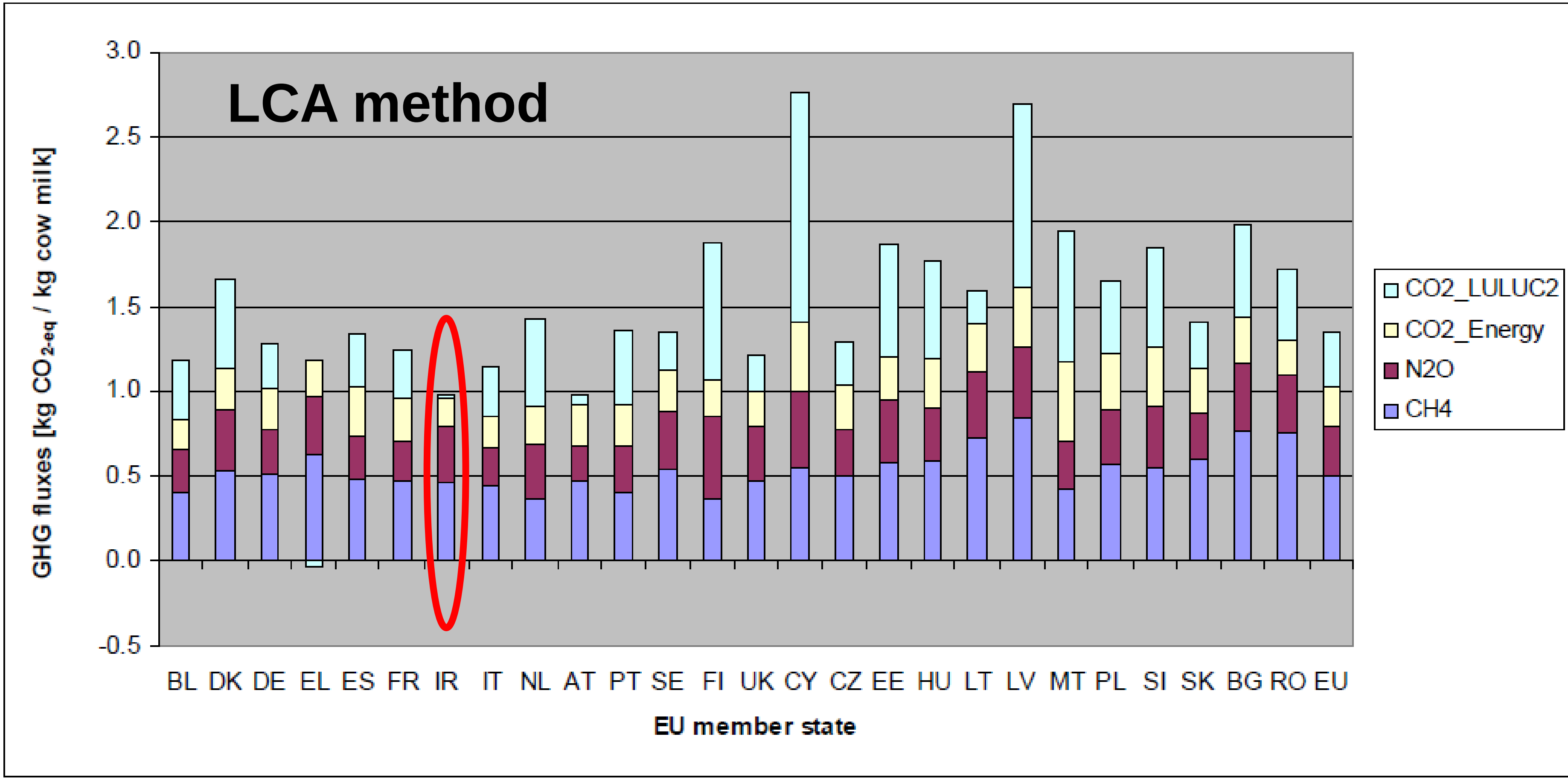
- Profitability of Irish dairying is closely linked to grass utilisation (tons DM/ha)
- Increasing SR only profitable when grass utilisation (tonnes DM/ha) increases



- Optimum Stocking rate for Dairy Farms in 2015

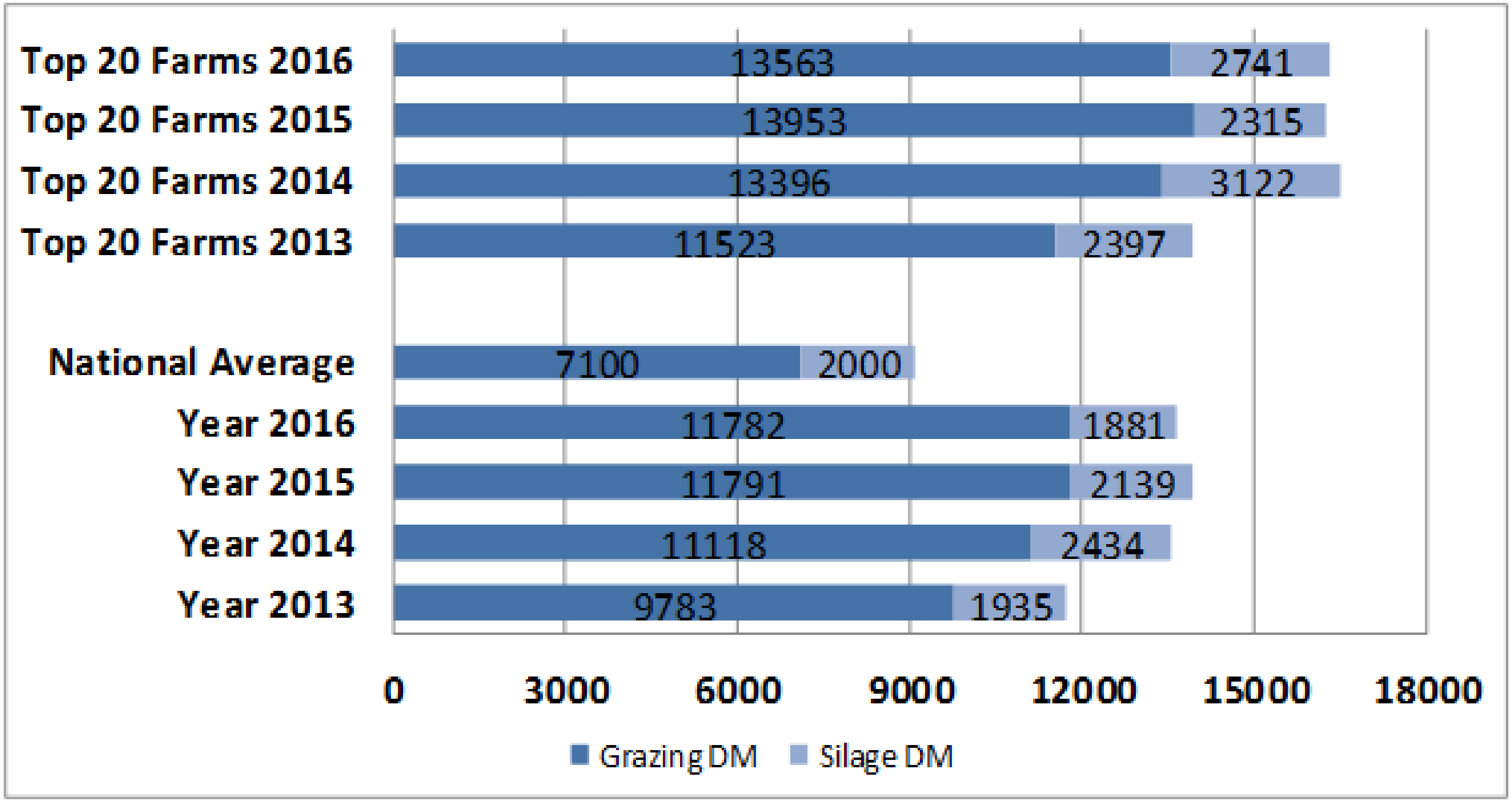
	Pasture grown, t			
t supplement DM/cow	10	12	14	16
0.00	1.5	2.0	2.3	2.6
0.25	1.7	2.1	2.4	2.8
0.50	1.8	2.2	2.5	3.0
0.75	1.9	2.3	2.7	3.1

Emissions per kg milk produced in different EU countries

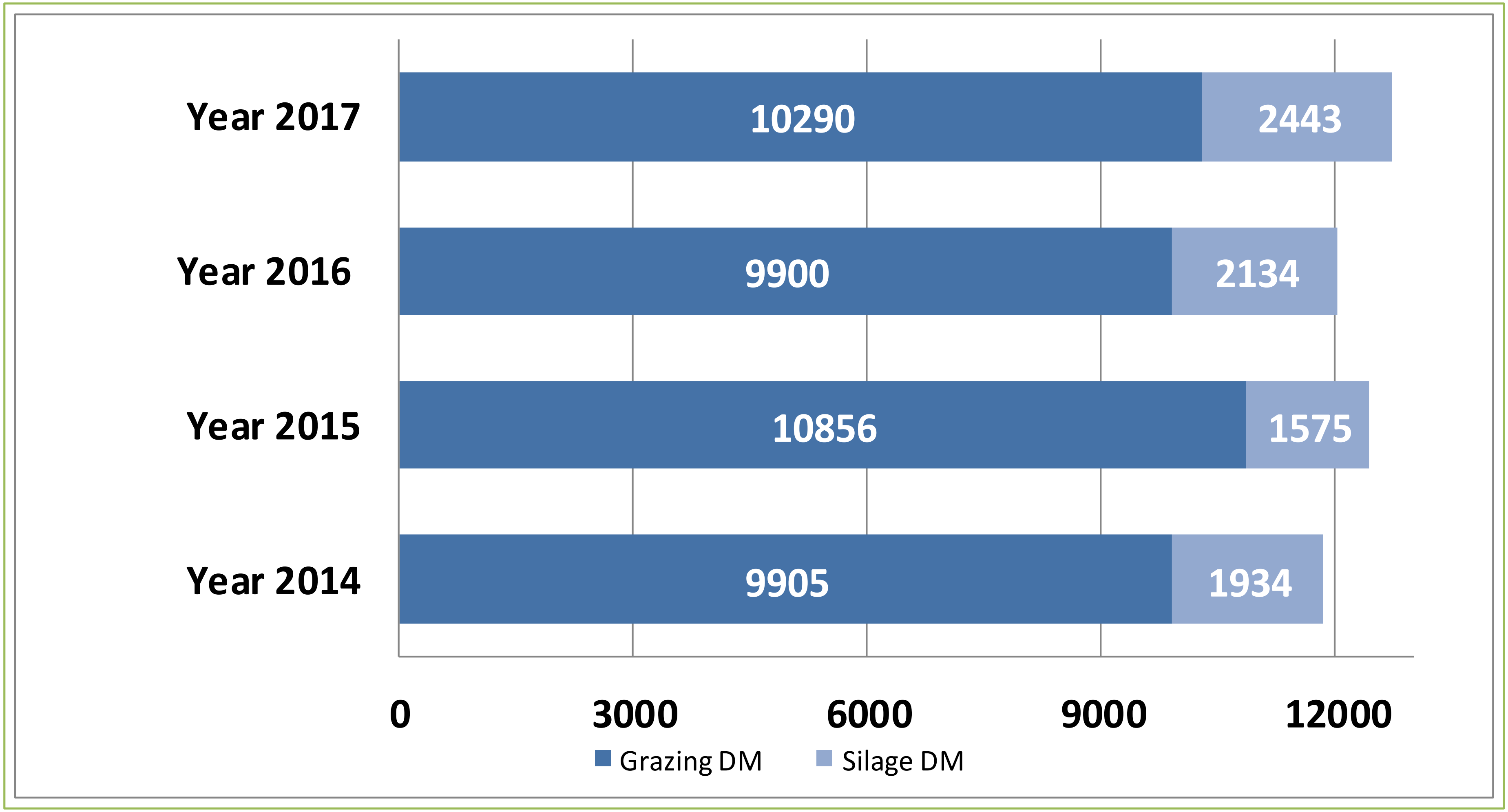


Source: Evaluation of the livestock sector's contribution to the EU GHG emissions (GGELS) **EC, Joint Research centre, 2010.**

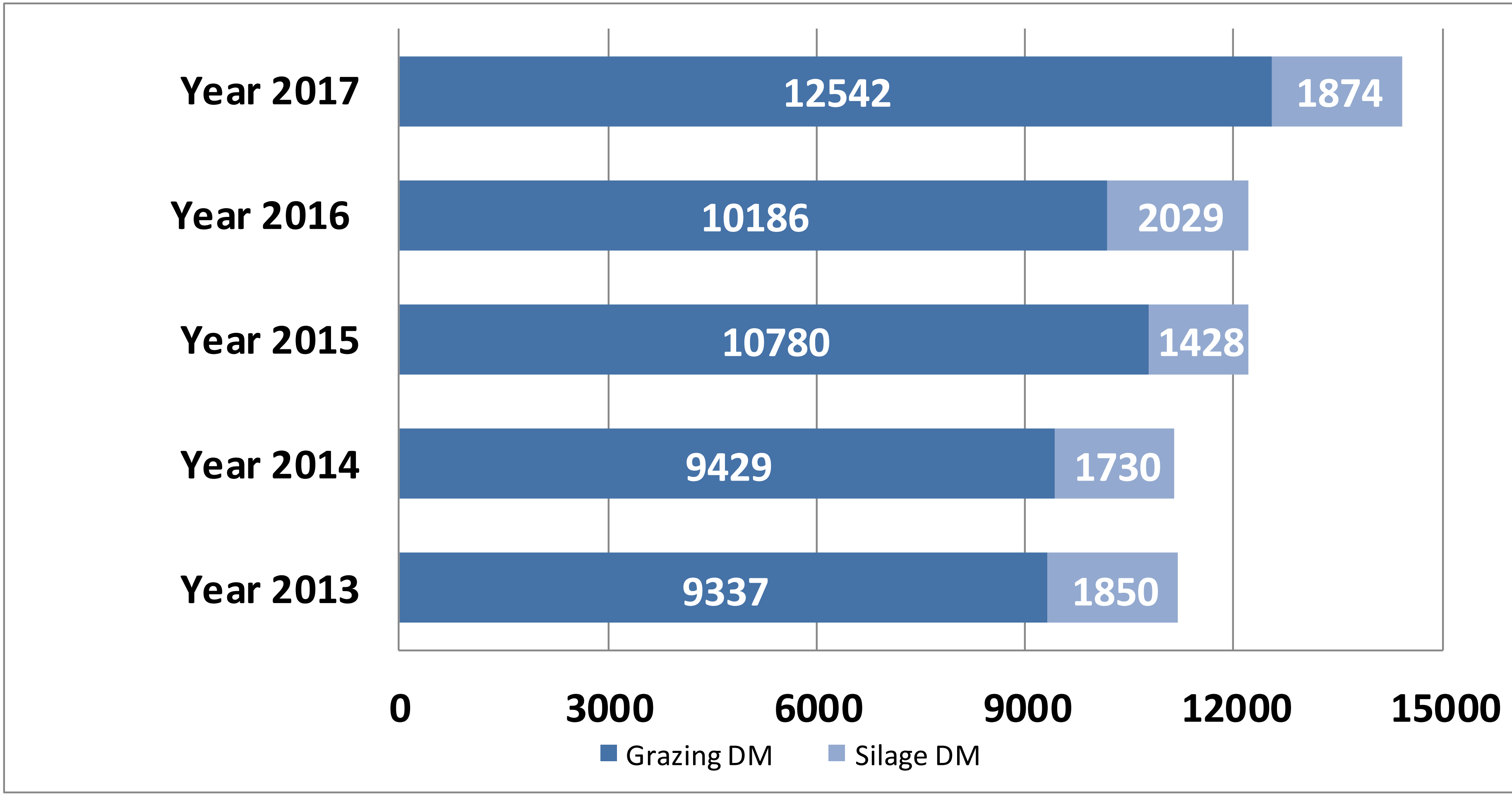
Pasturebase Ireland Dairy Farms DM Production/Ha



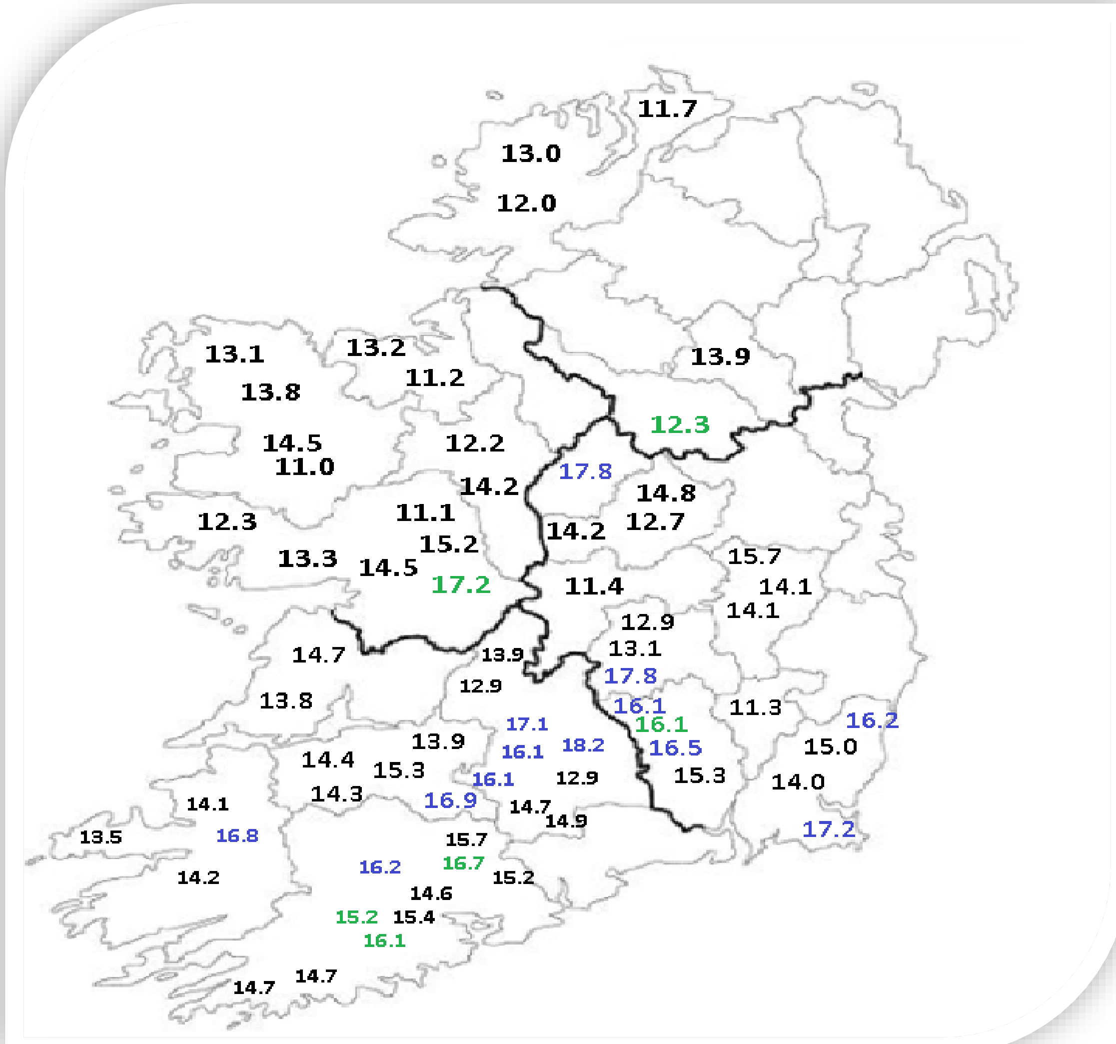
Grass DM Production - Beef



Grass DM Production - Sheep

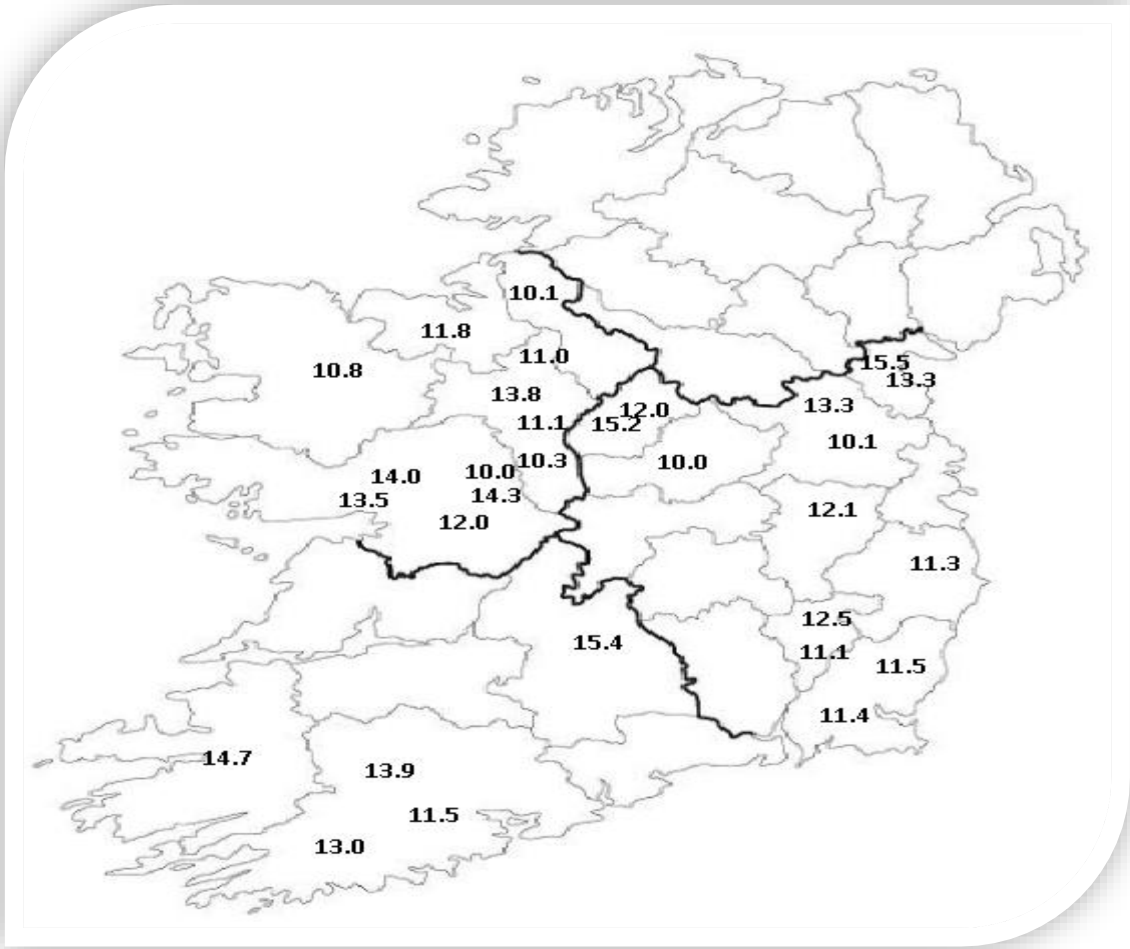


DM Production 2016 on Dairy Farms
Average DM Production 13.9 t DM/ha

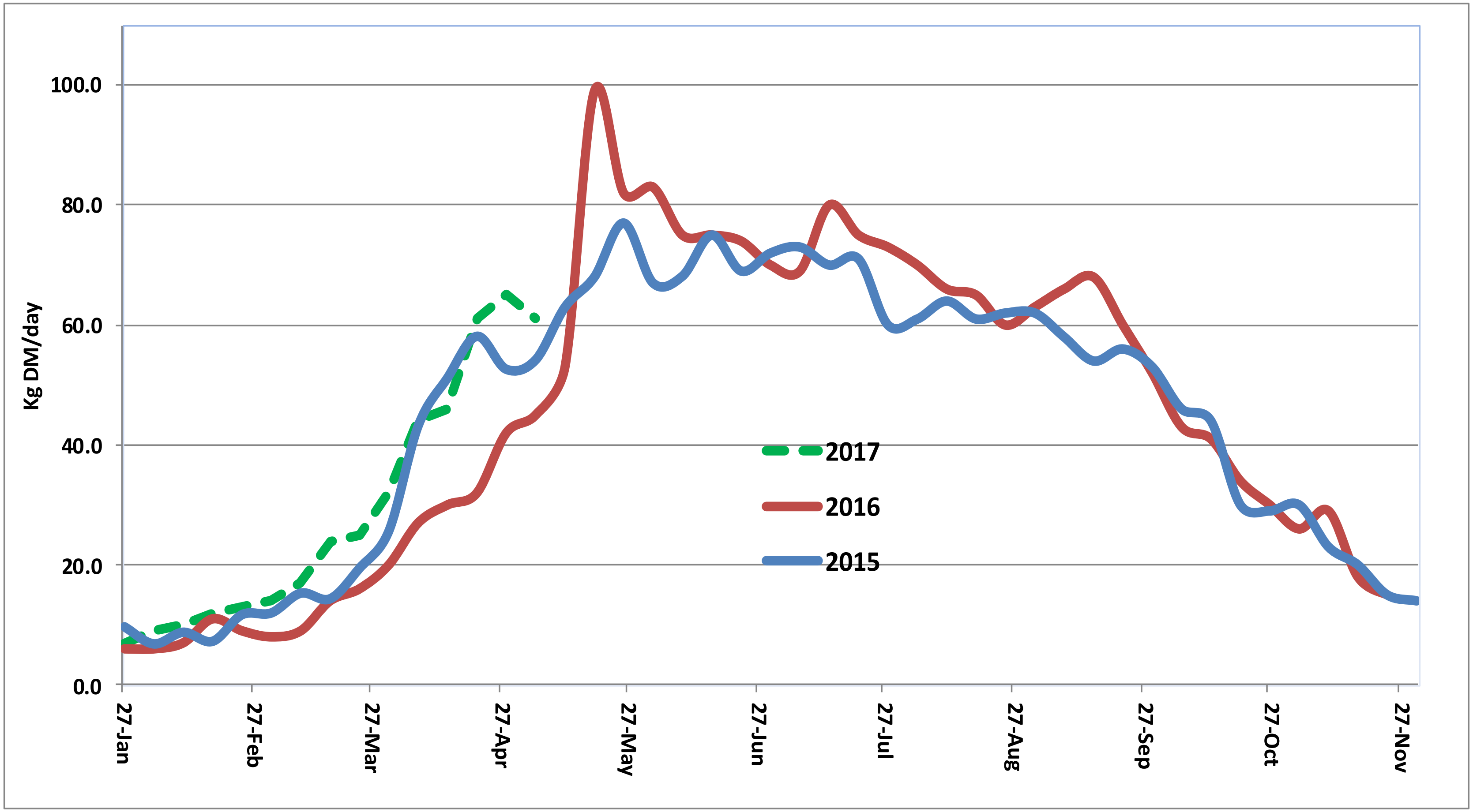


Agriculture and Food Development Authority

DM Production 2016 on Drystock farms
Average DM Production 12.2 t DM/ha



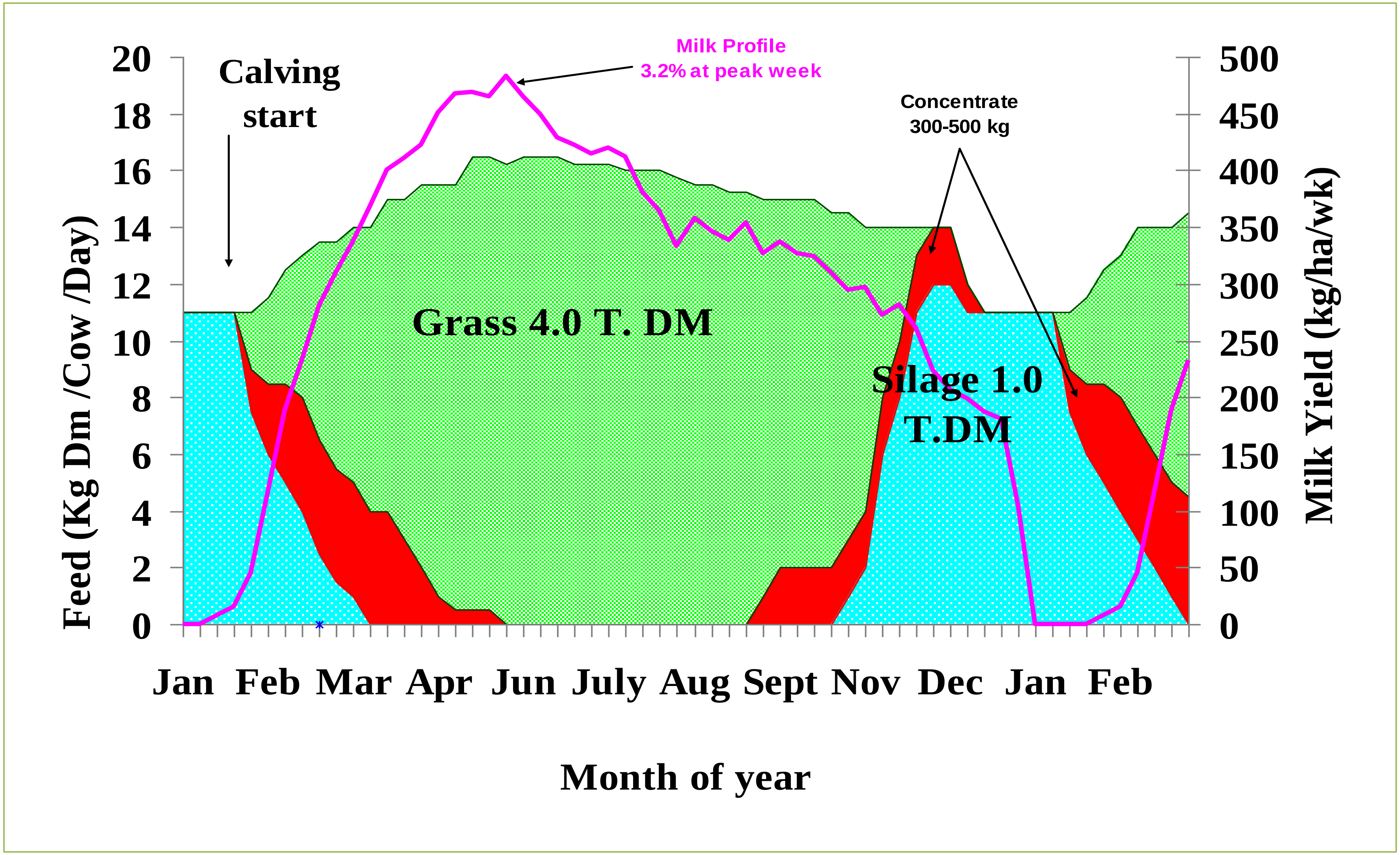
National Grass Growth Curve



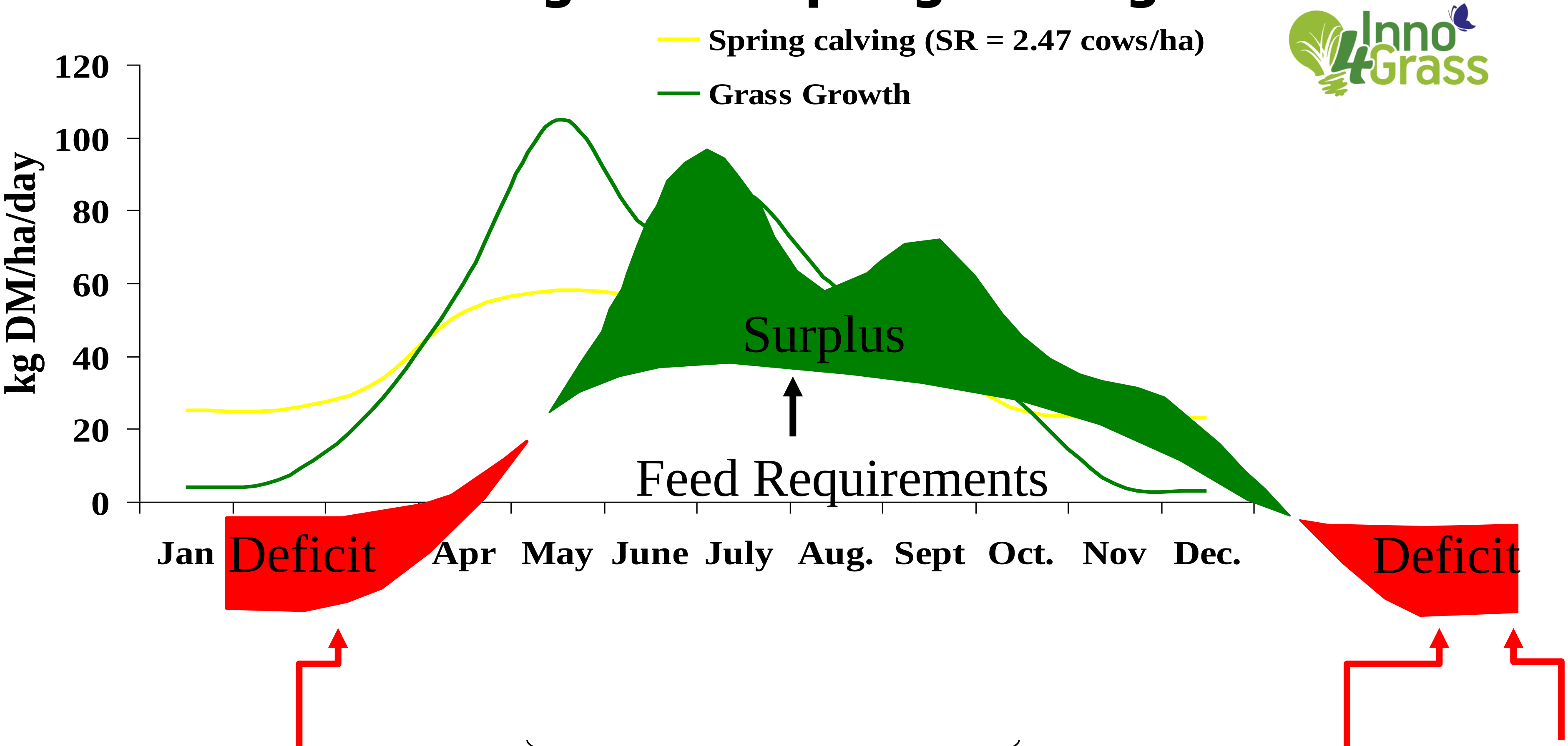
ESTABLISHED WITH THE GENEROUS FINANCIAL SUPPORT OF FBD Trust

Spring Milk Production

Milk 5,750 kg/cow
Fat 4.40%
Protein 3.60%
Milk solids 1,350kg/ha



The Grazing Year – Spring Calving Herd



Calving & Turnout

Mid-season

The Feed Wedge

Housing **Dryoff**

Spring

Spring Rotation Plan

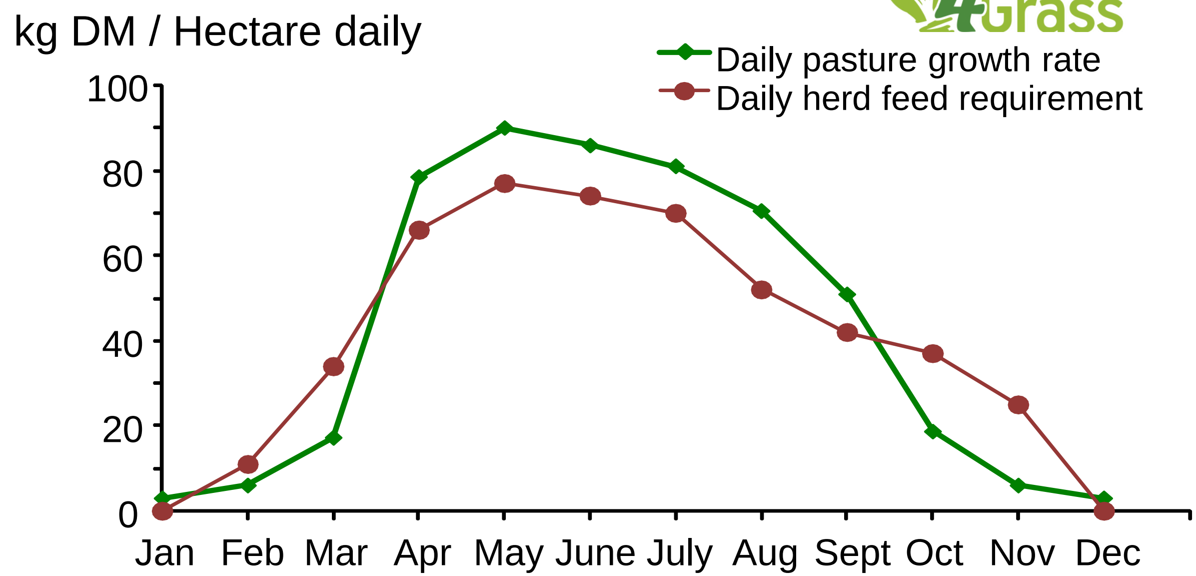
Autumn

Feed budgeting (60:40 plan)

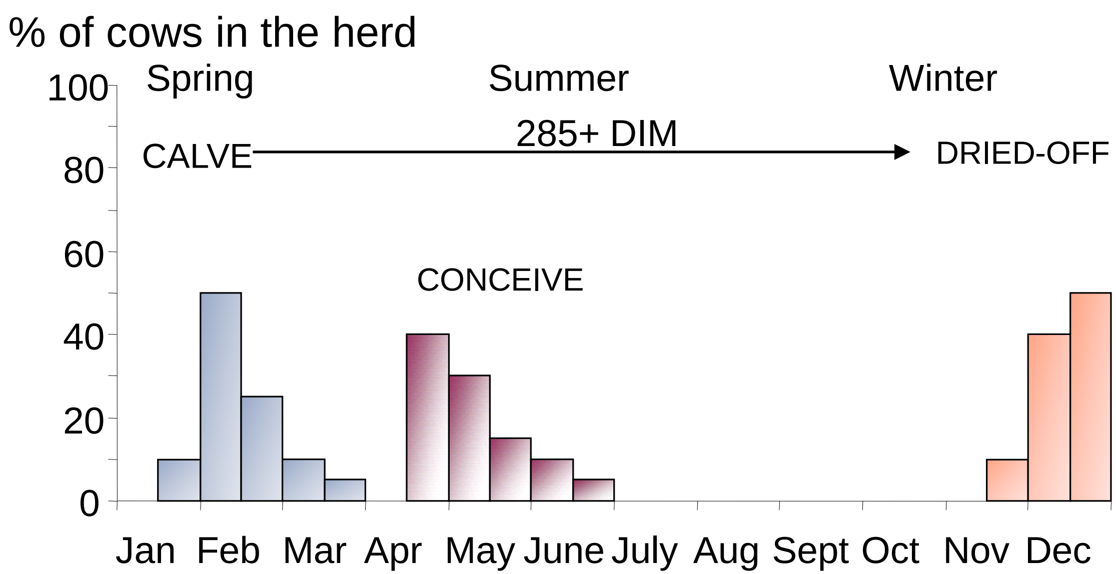
Integrated Grass-based Production Systems

Integrated decisions

Alignment of
grass supply
&
animal requirements



Compact calving, high fertility status dairy herd



"Simplicity is the ultimate sophistication" – Leonardo da Vinci.

Grazing Management Objectives

High Animal performance
Kg MS/hectare

High pasture growth
Low feed costs

1. Maximise the proportion of grass in the diet

2. Supply adequate green leaf to the cow while conditioning the sward for future grazing

3. Feed budgeting –
   - Achieve seasonal targets
   - Identify and react to surplus/deficit quickly

Spring Grazing Objectives & Guidelines

Why?

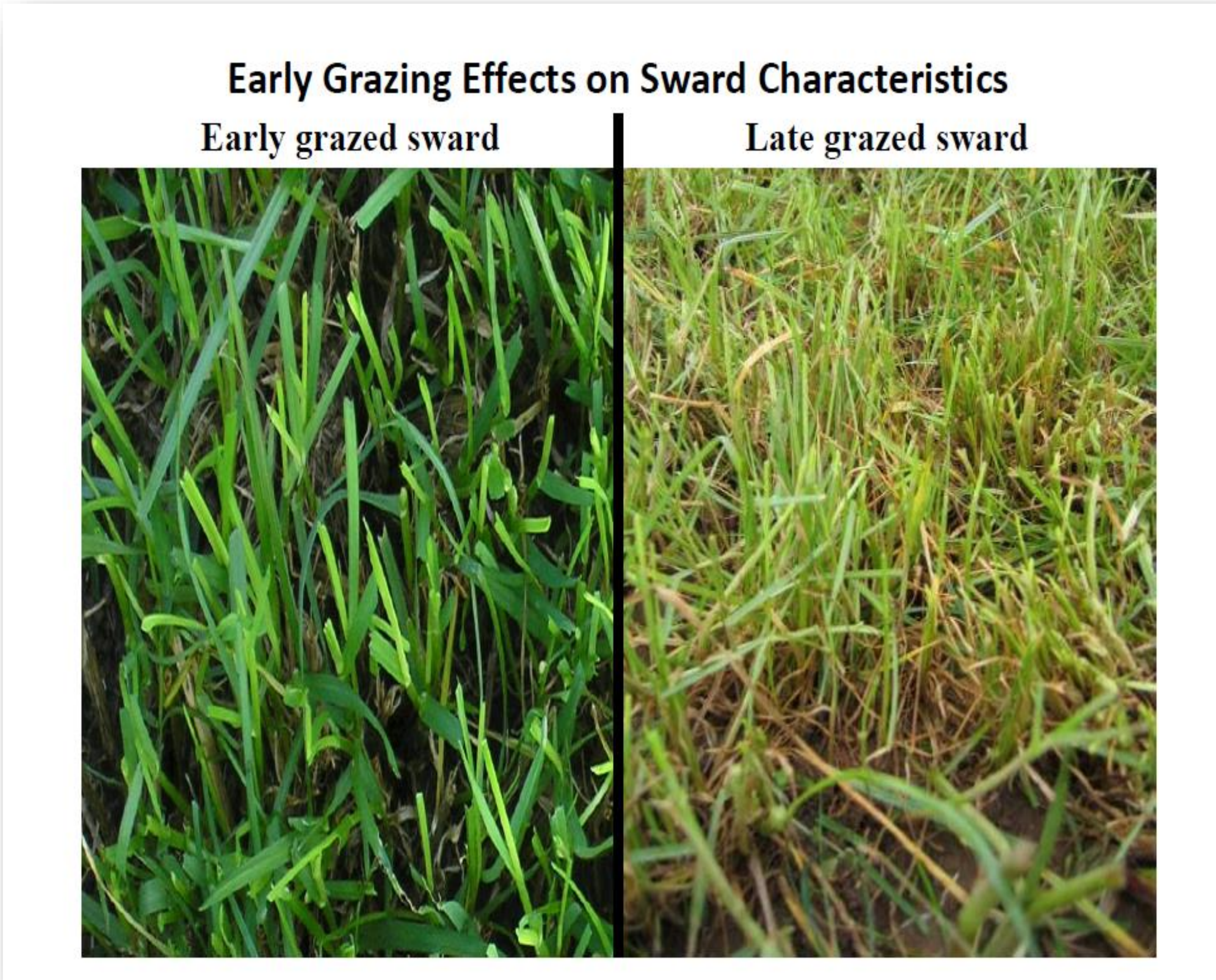
Get calved cows out to grass as early as possible

- Increased animal performance - high quality diet with minimal supplements
- Recondition swards for the year ahead – stimulate growth and improve quality
- Maximise spring grass utilisation & minimise sward decay
- Reduce workload on the farm

Each extra day at grass = €2.70/cow/day

How?

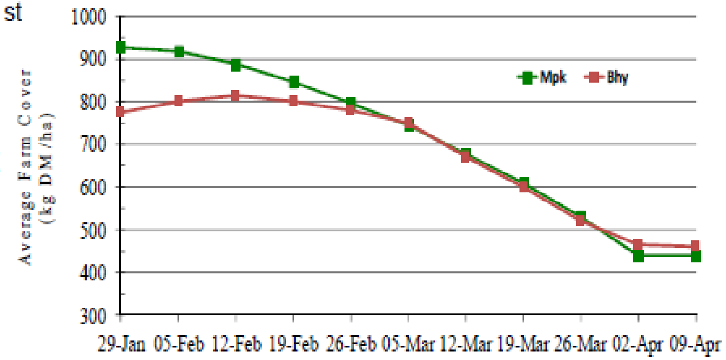
- Maintain target Average Farm Cover (AFC) each week during Spring
- Allocate spring grass based on Spring Rotation Plan (SRP)
- Achieve target post-grazing height of 3.5cm
    - maximise utilisation & recondition spring swards
    - enable plants to capture sunlight energy
- Steadily increase total feed allowance from calving into breeding
    - Maximise milk solids production and fertility performance & minimise BCS loss


Early Grazing Effects on Sward Characteristics
Early grazed sward
Late grazed sward

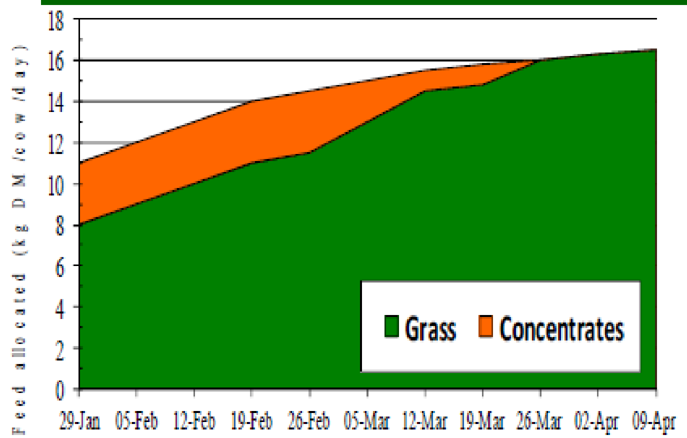
Target Feed Budget & Allowance

- The ideal average farm cover (AFC) of 800 - 900 kg DM/ha on February 1st
- High quality predominantly grass diet from calving
- Extend the 1st rotation from February 1st to early April with minimal supplements
- Feed allowances increasing by 0.75kg DM/cow/wk from calving to breeding

March Grass Growth increased by 3kg DM/day for every 100kg DM/ha increase in AFC



Spring Grass Allowance increased by 1 kg DM/cow/day for every 100kg DM/ha increase in AFC



Using the Spring Rotation Plan (SRP)

Example SRP for a 40 ha dairy farm with 100 dairy cows

Week	Rotation (days)	Daily area (ha/day)	Total area grazed by week end (%)
1st to 7th Feb	100	0.4	7
15th to 21st Feb	82	0.49	23
22nd to 28th Feb	73	0.55	33
8th to 14th Mar	56	0.72	56
22nd to 28th Mar	38	1.06	90
29th Mar to 4th Apr	29	1.38	114

For the plan to be successful

- Stick to the planned area
- Post-grazing residual 3.5cm
- Use a strip wire on a 12-hour basis.
- Grazing area should be back fenced
- On/Off grazing is essential in wet weather.

Fertiliser Recommendations: February/ March

- Spring Nitrogen (N) application is essential to boost growth on all paddocks

Average Grass Growth Response of 10 kg DM per 1 kg N applied per ha in Spring

Efficiency of slurry utilisation increased (x6) during February & March

High risk of N loss to groundwater (x25) during February & March

- Immediately after the closed period for fertilizer and slurry application
    - Apply 2,500 gals. slurry/ac. to 30% of paddocks (<650 kg DM/ha herbage mass)
    - Apply 23 units urea/ ac. to remainder (Urea= 30% cheaper than alternatives/kg N)
- In early March
    - Apply 2,500 gals. slurry/ac. to 30% of paddocks
    - Apply 40 units urea/ ac. to remainder
- 70 units N applied by April 1st
- Pay close attention to weather forecasts to avoid heavy rain and waterlogged soils within 48 hours of nutrient application to minimise losses and maximise benefits.

Mid Season Grazing Management

Getting it right during the main grazing season

DOs	DON'Ts
Walk the farm weekly	Walk farm fortnightly or less frequently
Keep monitoring the recovery of re-growths	Delay the reaction to high grass growth
React quickly to increasing grass growth	Let pre-grazing yields increase
Maintain pre-grazing yields at 1,300-1,600kg DM/ha (8-10cm)	Increase SR too much on grazing area, by closing paddocks for long-term silage
Graze paddocks out to 4-4.5cm	Graze paddocks to 5.0-5.5cm
Top only when necessary to 4-5cm	Extend rotation length >23 days
Keep rotation length at 18-21 days	
Continually react to changes in growth	
Take out paddocks quickly	

Grazing to 3.5-4cm in the first rotation provides a platform for excellent quality grass re-growth.

The ideal pre-grazing yield for maximum animal performance is 1,300-1,600kg DM/ha (8-10cm).

Under-grazing leads to a greater proportion of stem. This will lower grass quality and animal performance.

Avoid turning stock into too heavy covers. React quickly to surplus grass and save as baled silage.

Getting it right during the main grazing season

	Too low	Just right	Too high
Pre-grazing yield (kg DM/ha)	950 - 1,050	1,300 - 1,600	2,000 - 2,200
Pre-grazing height (cm)	6-7	8-10	12+
Rotation length (days)	14/16	18/21	26/30
Leaf content (%)	>70	>70	>60
Days ahead	10	14	22

Advantages of grazing a cover of 1400kg DM/ha and disadvantages of not

Advantages	Disadvantages
Have 7-9cm of grass (1400kg DM/ha) on paddocks for grazing next	Too much grass on farm
Have the recommended 10-14 days grass on the farm	Have 21-28 days grass on farm (double the requirement)
High grass quality - high leaf content	Poor grass quality and low utilisation
'Wedge' shaped supply – the most grass will be in the paddock to be grazed next and the least in the paddock grazed last	Post-grazing height too high
Have flexibility to close for silage	Will have to close >50% of farm to correct grass surplus
Little topping required	Two to three rounds of topping required
Higher weight gains	Weight gain poor

Autumn Grazing Management

Autumn grazing management

DOs	DON'Ts
Build grass from mid August	Build grass from mid July
Harvest excess grass as bales in August	Harvest grass as bales in September
Block graze the higher grass covers	Re-graze closed paddocks
Graze cover <2300kg DM/ha	Graze covers >2500kg DM/ha
Have the highest farm cover in mid September	Have the highest farm cover in mid October
Start closing paddocks in early October	Start closing paddocks in late October
Plan your closing rotation for the farm	Have no closing plan
Graze paddocks to 4cm	Graze paddocks to 5-6cm

Nitrogen and slurry applications in autumn

DOs	DON'Ts
Apply slurry to paddocks with low soil index	Use urea in dry periods
It may be possible to use urea when spreading N in autumn	Apply nitrogen to clover rich pastures
Apply low levels of nitrogen rather than missing N on paddocks	Miss nitrogen on paddocks if possible
Use light applications of slurry if available	
Apply a blanket application of nitrogen if required pre-September 15	

10 STEPS To managing a wet autumn

1 A flexible attitude – don't allow poaching.

2 Use most sheltered and driest paddocks when grazing in wet weather.

3 Strip grazing or block grazing can be used during wet weather to ensure minimal damage from poaching. Use one section per day to get the most from the grass.

4 Where possible, use a back fence. This will help to protect regrowths and prevent soil damage.

5 On/off grazing can be practised to reduce poaching damage and keep animals at grass for longer.

6 Have multiple access points into a paddock so that grazing animals do not have to use the same entrance. If you don't, create a 4ft to 5ft grass roadway on a fence line to get animals to the back of the paddock.

7 Strategically place water troughs in the paddock so that they will service several strips or blocks when a strip wire is being used.

8 Graze paddocks with heavy covers from the back of the paddock on the sheltered side.

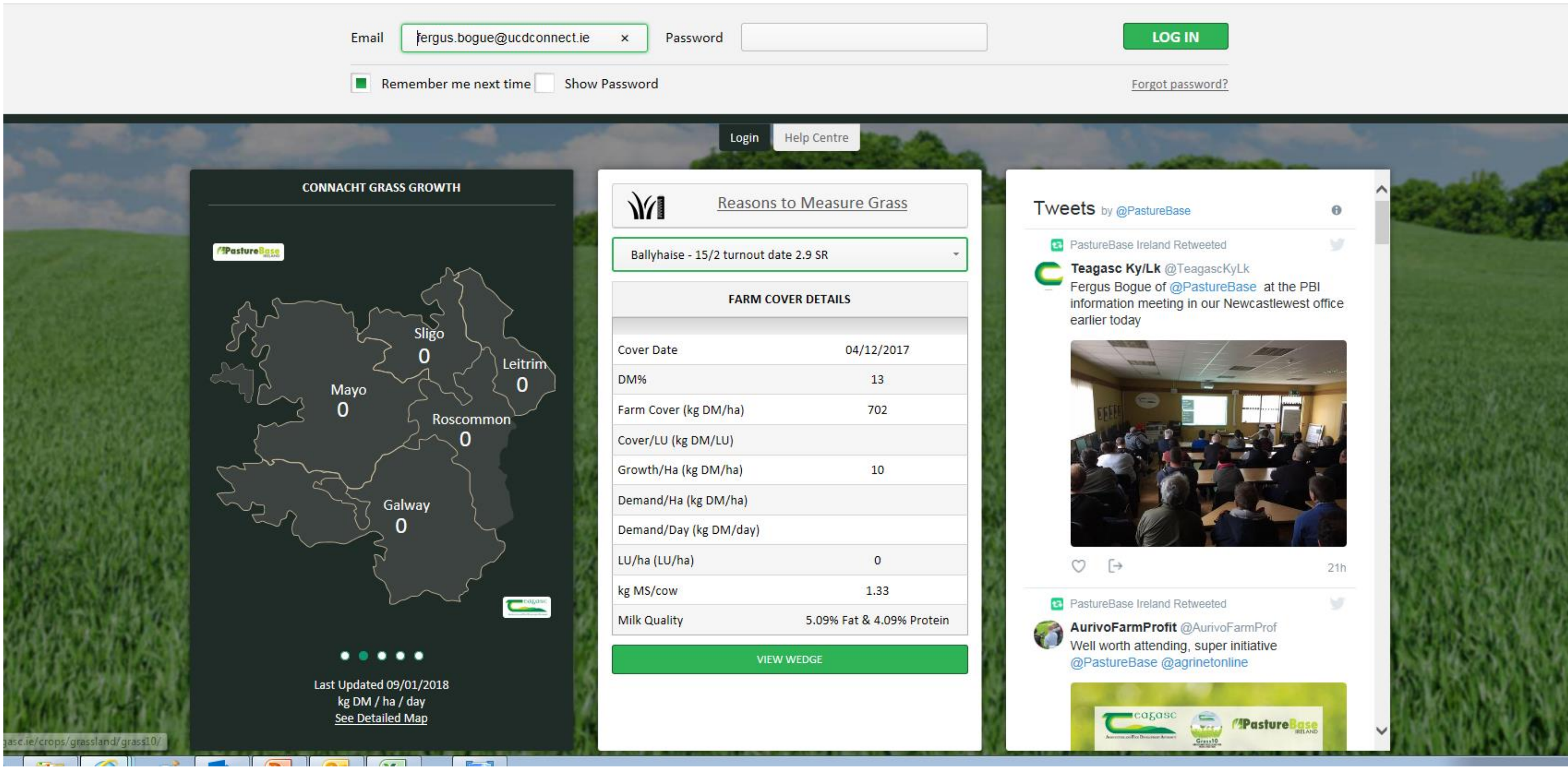
9 Change grazing break daily or every two days.

10 Change animals at the same time; give them a routine.

Inno4Grass

Teagasc
Agriculture and Food Development Authority

Management system
PastureBase Ireland



What is PastureBase Ireland & who should use it?

1. Grassland Management Support Software

2. Helps farmers to quantify the amount of grass on their farm

3. Any farmer that wants to increase the profitability of their farm

4. Currently >5,000 farmers on the system

PastureBase IRELAND

Inno4Grass

- Web based grassland management decision support tool
- National Grassland Database
- Farmer captures the data
- Core measurement is pre-grazing cover per paddock

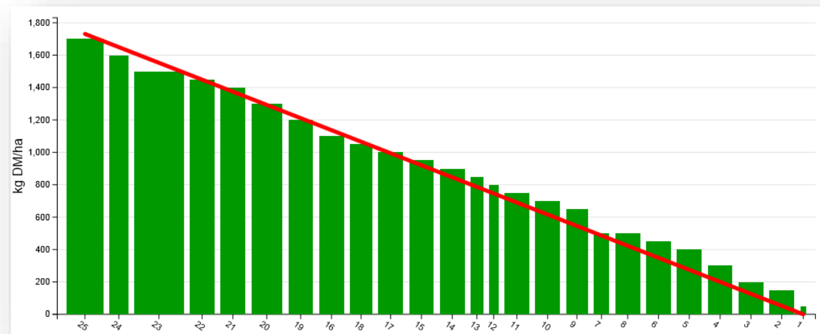
What tools are included in the application?

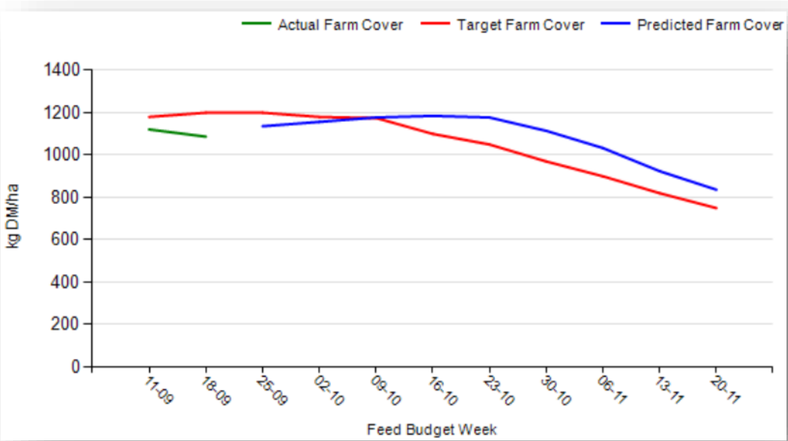
1. Summer Wedge

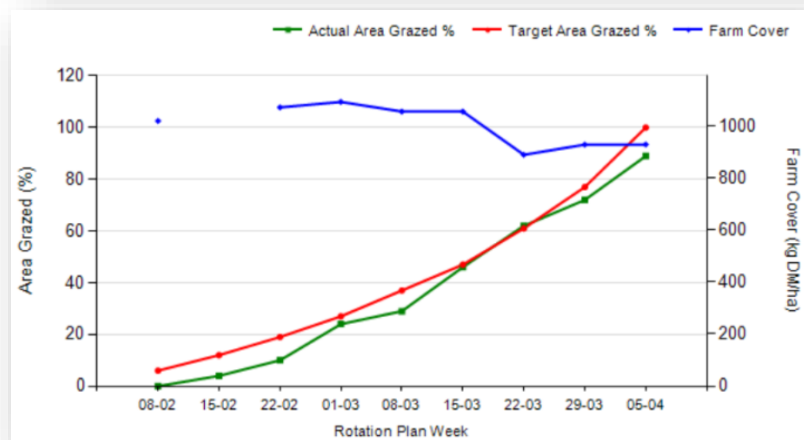
2. Spring & Autumn Rotation Planners

3. Feed Budget

4. Fertiliser/Slurry application







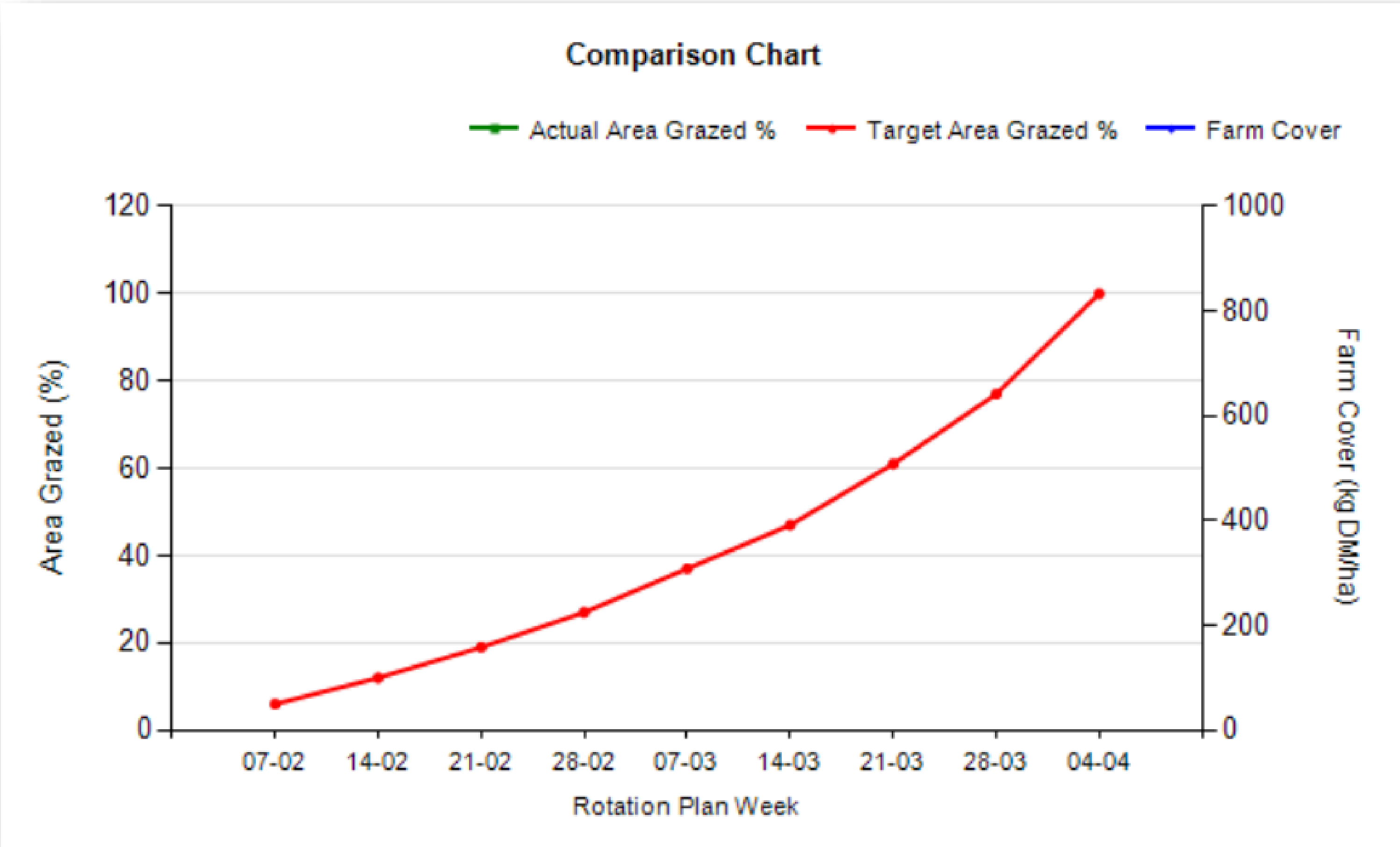
Who is using PastureBase Ireland?

- >3000 farms
- >2500 Dairy farms
- 500+ Drystock farms
- 270 – Dairy and Drystock advisors and industry personnel
- 8 Teagasc Research farms
- 6 Agricultural Colleges
- Aiming to increase usage to 4,000 farmers actively measuring in ‘18

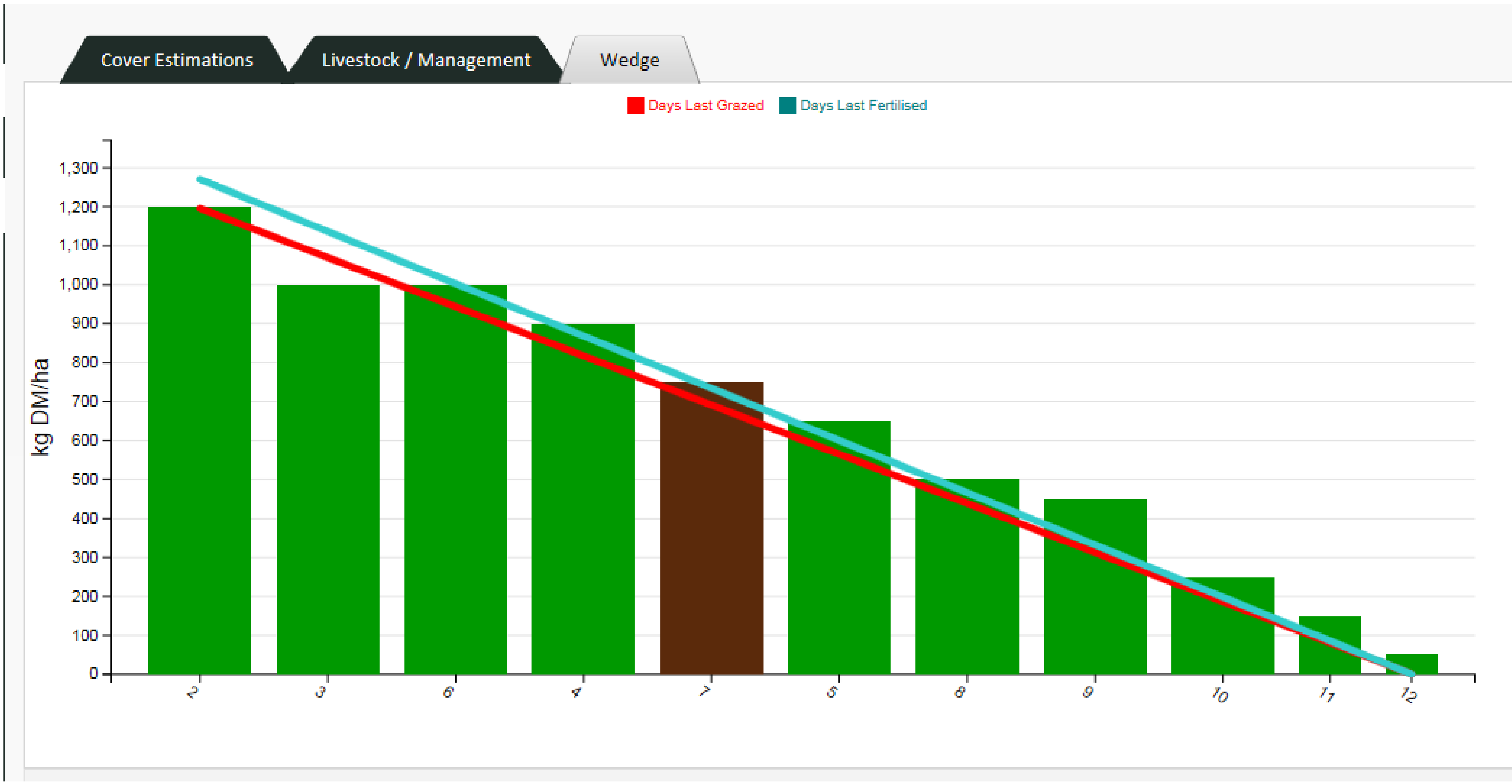
Spring Rotation Planner: 40 ha Farm

Week	Total area grazed by week ending (%)	Cumulative area grazed (ha)/ week ending	Pregrazing Herbage Mass on April 5th (kg DM/ha)
1st to 7th Feb	7	2.8	800 - 1,200
8th to 14th Feb	14	5.6	
15th to 21st Feb	21	8.4	
22nd to 28th Feb	30	12	
1st to 7th Mar	45	18	400 – 800
8th to 14th Mar	60	24	
15th to 21st Mar	73	29.2	
22nd to 28th Mar	87	34.8	100 - 400
29th Mar to 4th Apr	100	40	

Spring Rotation Planner



Grass Wedge- Identifying a grass Surplus/Deficit on the Farm

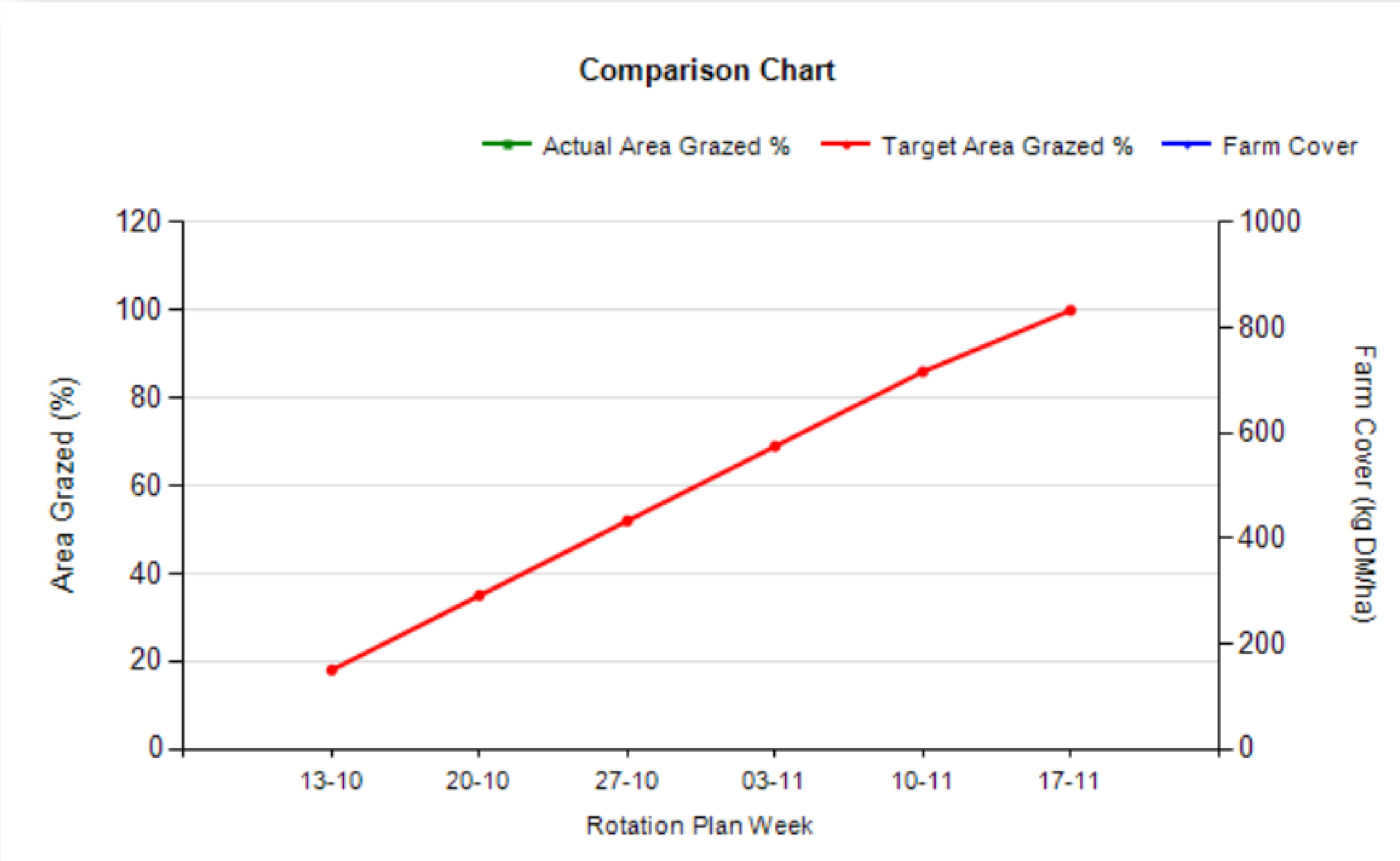


Grass Wedge- Data Generated to make Decisions

Farm Cover (kg DM/ha)	Help	481
Cover / LU (kg DM/LU)		153
Growth / ha (kg DM/ha/day)	Help	43
Demand / ha (kg DM/ha/day)	Help	50
Demand / day (kg DM/day)		560
Days ahead	Help	10
Kg LWT / ha	Help	72

Total LU	Help	35
LU / ha		3.15
Grazing Area		9.10 ha (10)
Silage - Cut Later		0.00 ha (0)
Silage - Cut Now		2.00 ha (2)
Reseed		0.00 ha (0)
Other		0.00 ha (0)

Autumn Rotation Planner

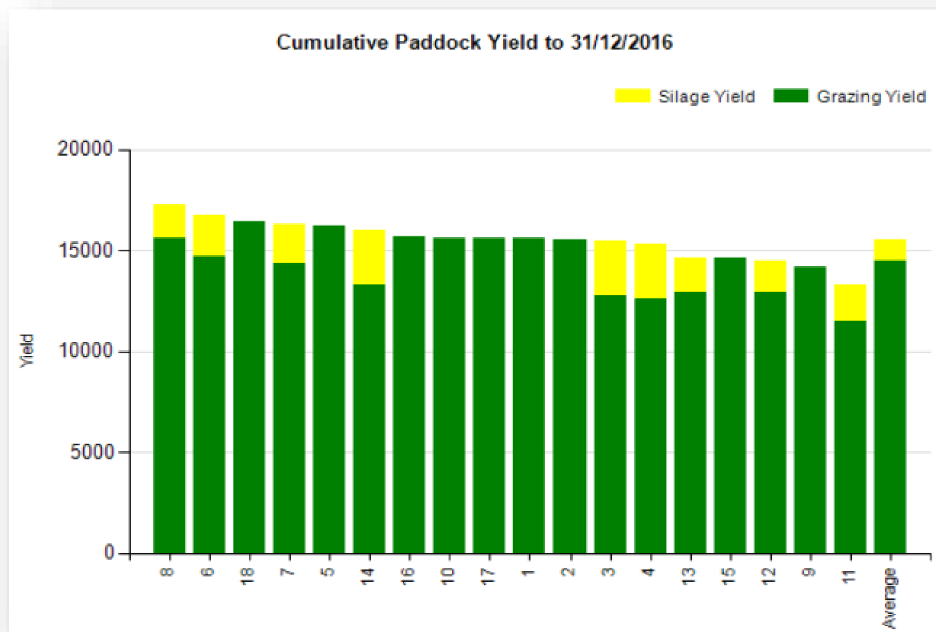


Requirements of the ideal grass

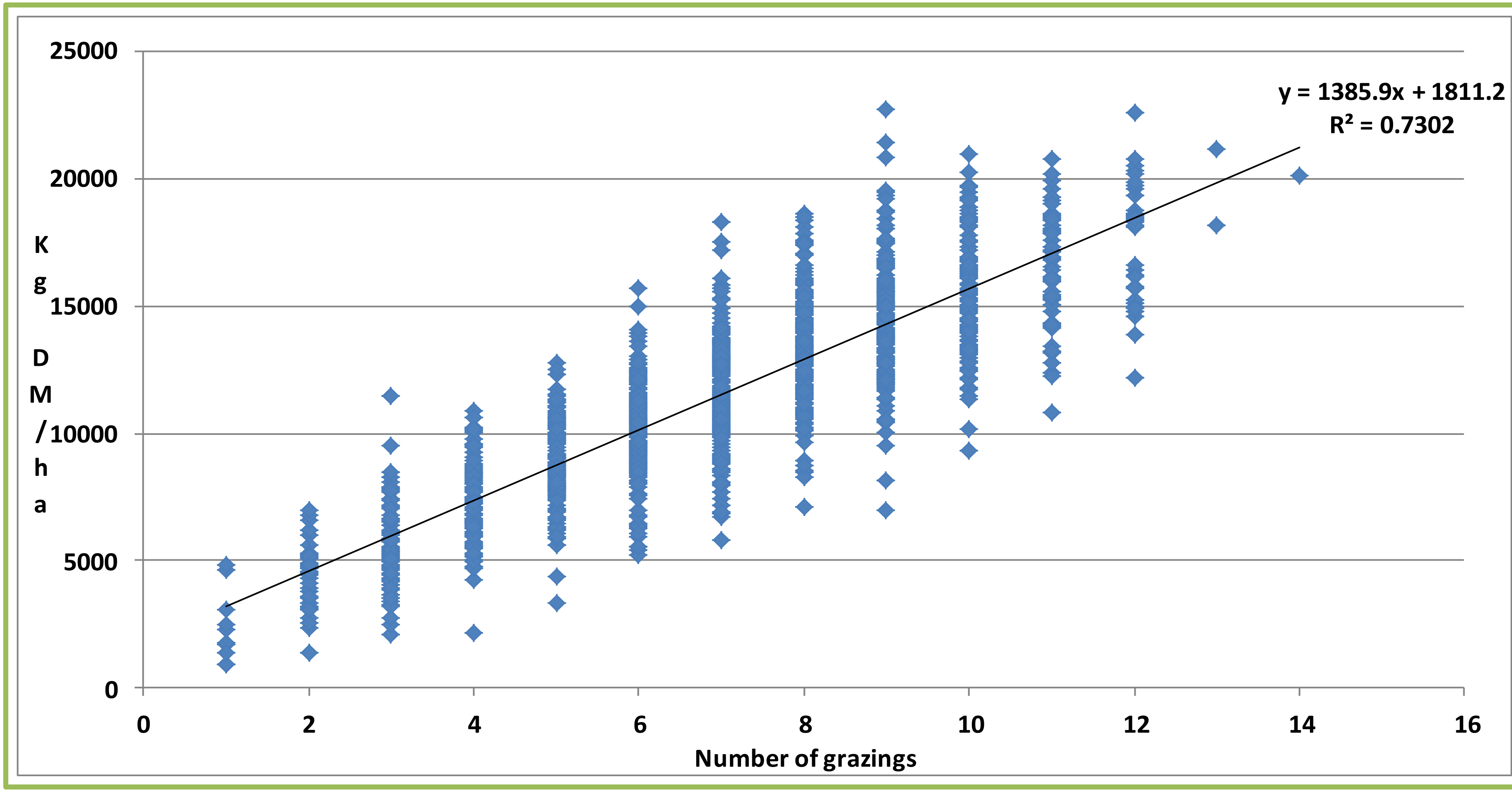
Grass DM Production (t DM/ha)	17-18
Energy level (UFL)	>1
Organic matter digestibility (%)	82-86
CP (g/kg DM)	170-200
NDF (g kg/DM)	350-450
Dry matter (g kg DM)	150-210
Green leaf mass (%)	>80
No reheading, high nutrient efficiency	
Grass intake mid season (kg DM/cow)	18-20
Sward persistency (years)	7 - 10

What are high producing farms doing ?

- High Soil fertility – Index 3, pH >6.0
- Weekly measurement and proactive management
- Low variation between highest and lowest paddocks
- Spring grazing
- More grazings per farm
- Reseeding part of management



Number of grazings achieved and its association with total grazing DM production



15 Tonne Grass Map

Growth Period	Grass grown (kg/ha)	Rotn. Length (days)	No. of Rotations	Growth (kg/ha) required/day
1st Feb – 6th April	1250	65	1	20
7th April – 5th Aug	1,500	20	6	75
6th Aug – 1st Sept	1,625	25	1	65
1st Sept - 1st Oct	1,650	30	1	55
1st Oct – 15th Nov	1,450	45	1	30
Total	15,000	287	10	

What has PastureBase Highlighted?

- **DM production** can **increase** on all grassland farms
- Variation **across** and **within** farms
- **Regional effect** on DM production is **minimal**
- **Management** is key to increase DM production
- Huge **variation** in **spring** DM production on farms nationwide
- **Average farm cover** at closing and at the **start and end of the first rotation** are critical targets for all grassland farms

The Netherlands

Inno4Grass – Education material on practical grassland management of The Netherlands

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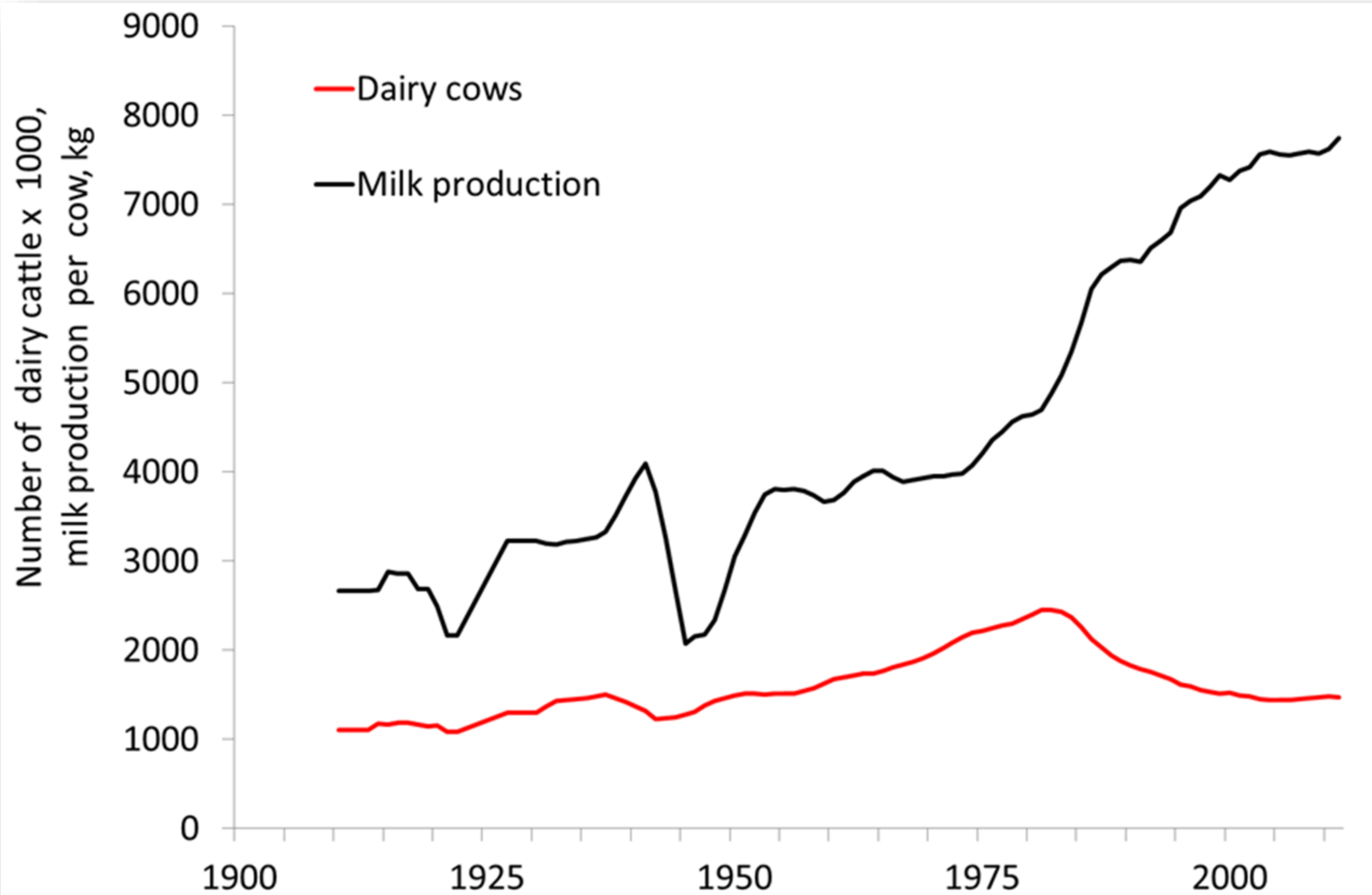
The Inno4Grass Project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727368.

The Dutch dairy sector 2017

- 17.000 dairy farms
- Average size 90 cows
- 50 ha, 8000-8500 kg milk per cow per year
- 11 billion kg milk before abolishment quota
- 80% FrieslandCampina
- 1.900.000 ha agricultural area
- 1.000.000 ha grassland
- 250.000 ha silage maize
- Large area for dairy farming

Developments

Source: CBS



In 50 years

- Average number of dairy cows per farm increased ten-fold, to about 85
- Average milk production per cow doubled to somewhat more than 8,000 kg
- The milk production per ha trebled to about 15,000 kg ha^{-1}
- A ten-fold reduction in the number of dairy farms to about 18,000.
  - *Van Dijk, Schukking, Van der Berg, 2015. Grassland Science in Europe 20: 12-20.*

Some characteristics of the Dutch dairy sector

- Regional differences in soil quality
- 60% of NL below sea level (-1 to -7m)
- Areas above sea level originally mostly poor sandy soils, fertilisation increased soil mineral content
- Average net yield of grasslands 9 – 11 tonnes DM yr^{-1}
- Rations characterised by relatively large amounts of supplementation, mainly maize silage, grass silage and concentrates

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Trends about grazing in the Netherlands

- Less grazing (90% of dairy cows in 2001, 70% in 2013, 65% in 2016, 68% in 2017)
- Less hours per day grazing
- Mainly rotational grazing, continuous stocking is increasing
- Less grazing in south and east
- Convenant Weidegang (Treaty Grazing)
- Grazing premium
- Grazing more prominent in education and science
- Social issue

- **<u>Political Parties proposed an obligation to graze</u>**
  - Proposal got a majority
- New government recently decided not to translate this into legislation (till 2020)

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Grazing = Societal issue?

- In the Netherlands: yes!
- Cultural heritage, animal welfare

- Started around 2000
- 2012: “Convenant Weidegang” (“Grazing Convenant”)
- Aim: stable number of grazing cows
- ~ 75 parties signed the Treaty by now

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18 June 2012 – Convenant Weidegang "Grazing convenant"

Source: Duurzame Zuivelketen

Grazing Convenant

- Dairy farmers: e.g. LTO Nederland
- Dairy industry
- Feed industry: e.g. Agrifirm, For Farmers
- Banks: e.g. ABN AMRO, Rabobank
- Accountants: e.g. Accon AVM, Alfa
- Semen industry, veterinarians, cheese sellers
- AMS industry: Lely, DeLaval
- Retail: Albert Heijn, Jumbo Supermarkten
- NGO's: Dierenbescherming, Natuur & Milieu
- Nature conservation: Staatsbosbeheer, Natuurmonumenten
- Government
- Education and science

DUURZAME ZUIVELKETEN

The Dutch Dairy chain is commited to the preservation of grazing. Chain-wide, this is supported by the Grazing Covenant. From every corner in the sector, people and companies work to increase the percentage of dairy farmers who apply grazing. Knowledge is being developed and widely spread via research and education, financial incentives are given and new 'grazers' are guided by GrazingCoaches. In 2017, cows were grazing on 80,4% of the farms.

Goals

- Grazing kept at least at its 2012 level: 81,2%

Method

The Dairy Sustainability chain has multiple incentives for dairy farmers to get their cows grazing (again). Every dairy company stimulates farmers financialy, called grazing premium. The grazing percentage is monitored independently.

Activities

- The Grazing Covenant exists since 2012. In December 2017, there are 82 signatories. Each signer is actively engaged in promoting grazing. They are very different companies and institutions: NGOs, supermarkets, research and educational institutions, dairy processors and feed suppliers
- Another initiative is guidance course New Grazers. During this course, special GrazingCoaches guide dairy farmers who want to switch to grazing. Dairy farmers who follow the course, get a GrazingCoache who guides them for two grazing seasons. They give tips and support, so the farmer can fit grazing well in his management.
- The project Amazing Grazing focusses on applying new scientific knowledge and solutions. All aspects of grazing are discussed: grass intake, behaviour of the cow, supplemental feed, grass supply, grass growth, and soil
- A pilot has started to develop measuring systems, that register grazing digitally. Sensors in the gates to the field and in the collar of the cow, allows it to sow that grazing is being applied. This is important, for example, in flocks that graze on different times or on farms with a milking robots in combination with free cow traffic

Grazing premium

- Grazing premium:
  - CONO as first dairy company
  - 2012: FrieslandCampina (0.5 ct/kg), Rouveen
  - 2013: DOC Kaas, Vreugdenhil, Bel Leerdammer
  - 2015: FrieslandCampina (1 ct/kg)
  - 2016: CONO (2 ct/kg)
  - 2017 and 2018: FrieslandCampina (1.5 ct/kg)

- Dairy farm of 1.000.000 kg milk: 15.000 Euro

- Definition of grazing for the premium
  - Minimum 120 days 6 hours per day

  - Also a smaller premium available for 25% of the herd grazing

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Reasons for less grazing

- To control rations and optimise grassland utilisation
  - When fed on grass only, DMI = enough to meet requirements of maintenance and 22-28 kg milk
- Increased herd size
- Increased use of automated milking systems
- Reduced grass growth in summer time
- Grazing “doesn’t sell”
- Need to reduce mineral losses
- Labour efficiency

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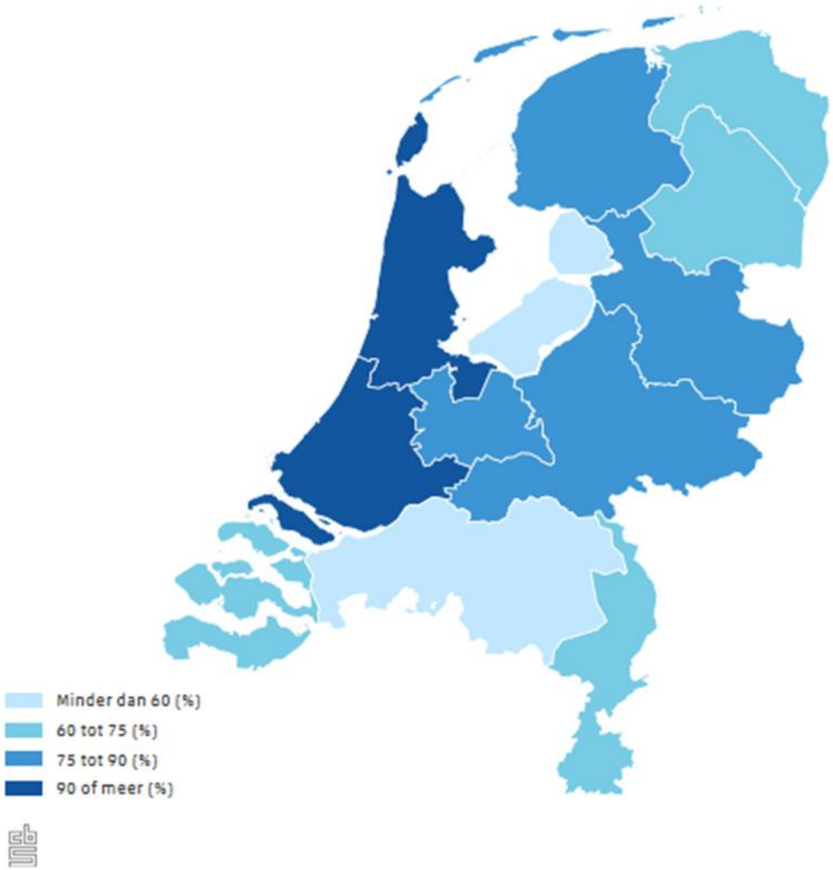
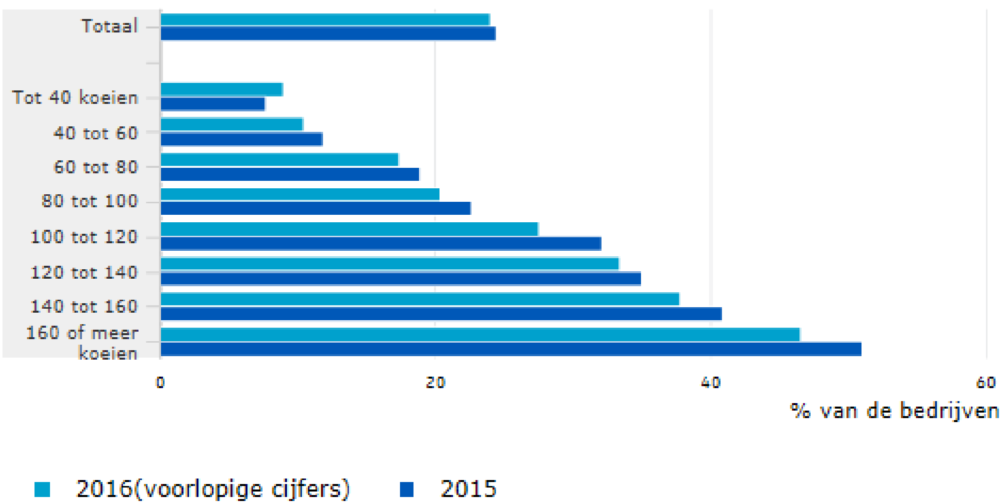
Grazing in the Netherlands, % cows grazing

% cows grazing per region



Effect of herd size – large herds start grazing (% non-grazing)



CBS, 2017

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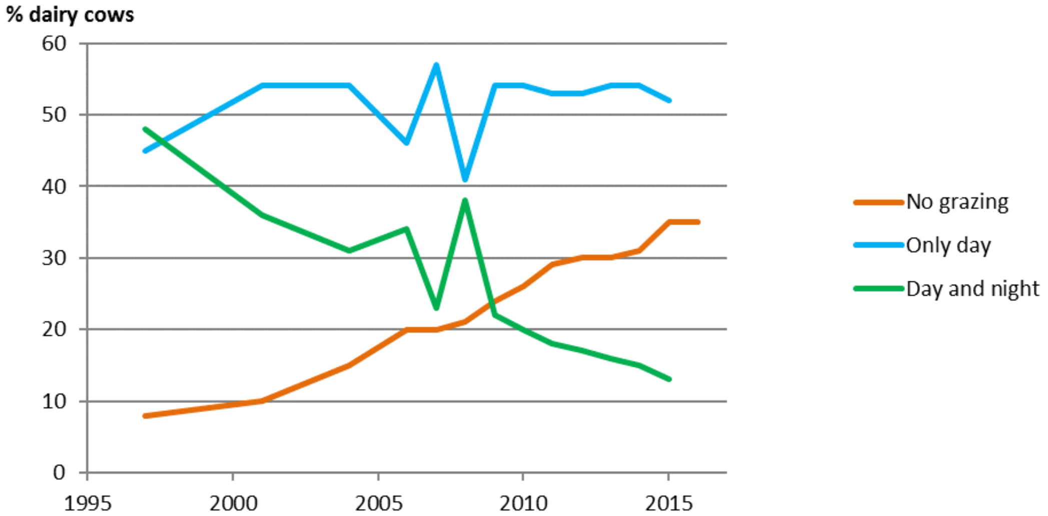
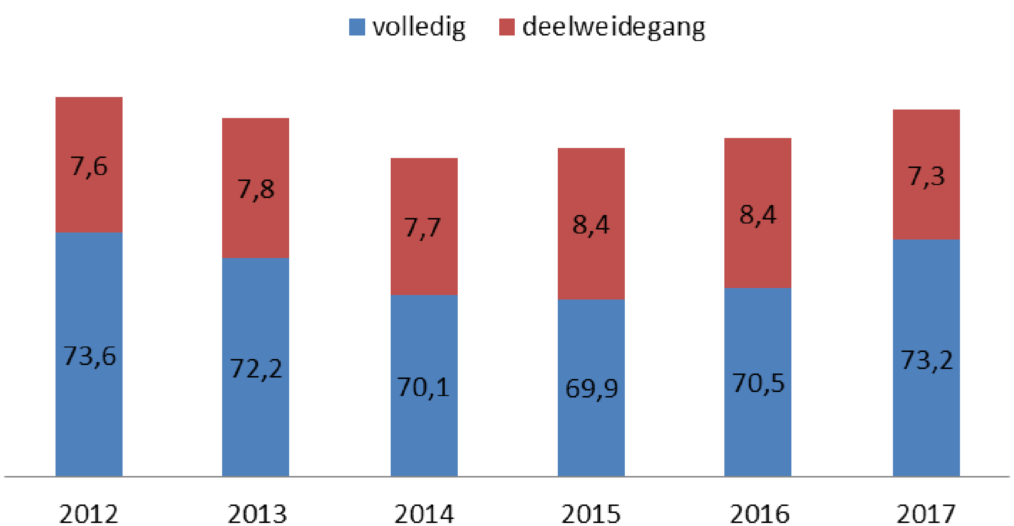
Grazing in the Netherlands



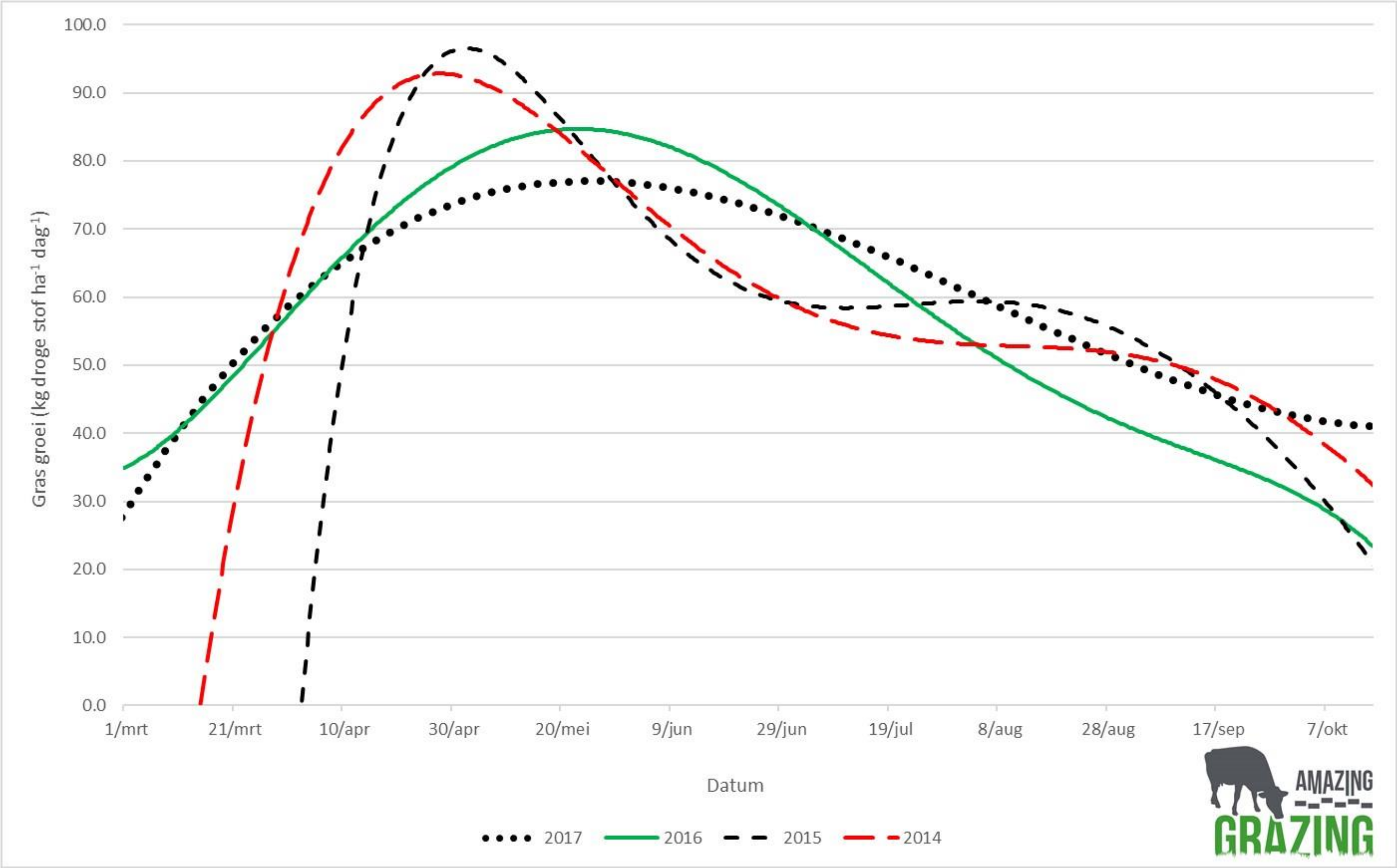
CBS, 2017

Percentage of farms with grazing increases again



Source: Duurzame Zuivelketen

Grass growth 2014-2017



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The effect of grazing on various aspects

The effect of grazing (unrestricted grazing, restricted grazing, no grazing) on various aspects. The score ranges from - - to ++, with ++ signifying that the system concerned scores positive for the point in question, e.g. high health, low losses.			
	Unrestricted	Restricted	No grazing
Grass yield and grass use	-	+	+
Balanced diet	-	+/-	++
Natural behaviour	++	++	+
Animal health	++	+	+/-
Nitrate leaching, N_2O emission	-	+	++
Ammonia volatilisation	++	+	+/-
N losses	-	+	++
P losses	-	+/-	+
Energy use, CH_4 emission	+	-	- -
Fatty acid composition of milk	++	+	+/-
Labour: hours work per year	++	+	+
Economics	+	+	-
Image of dairy farming	++	+	-

Van den Pol-van Dasselaar, 2008

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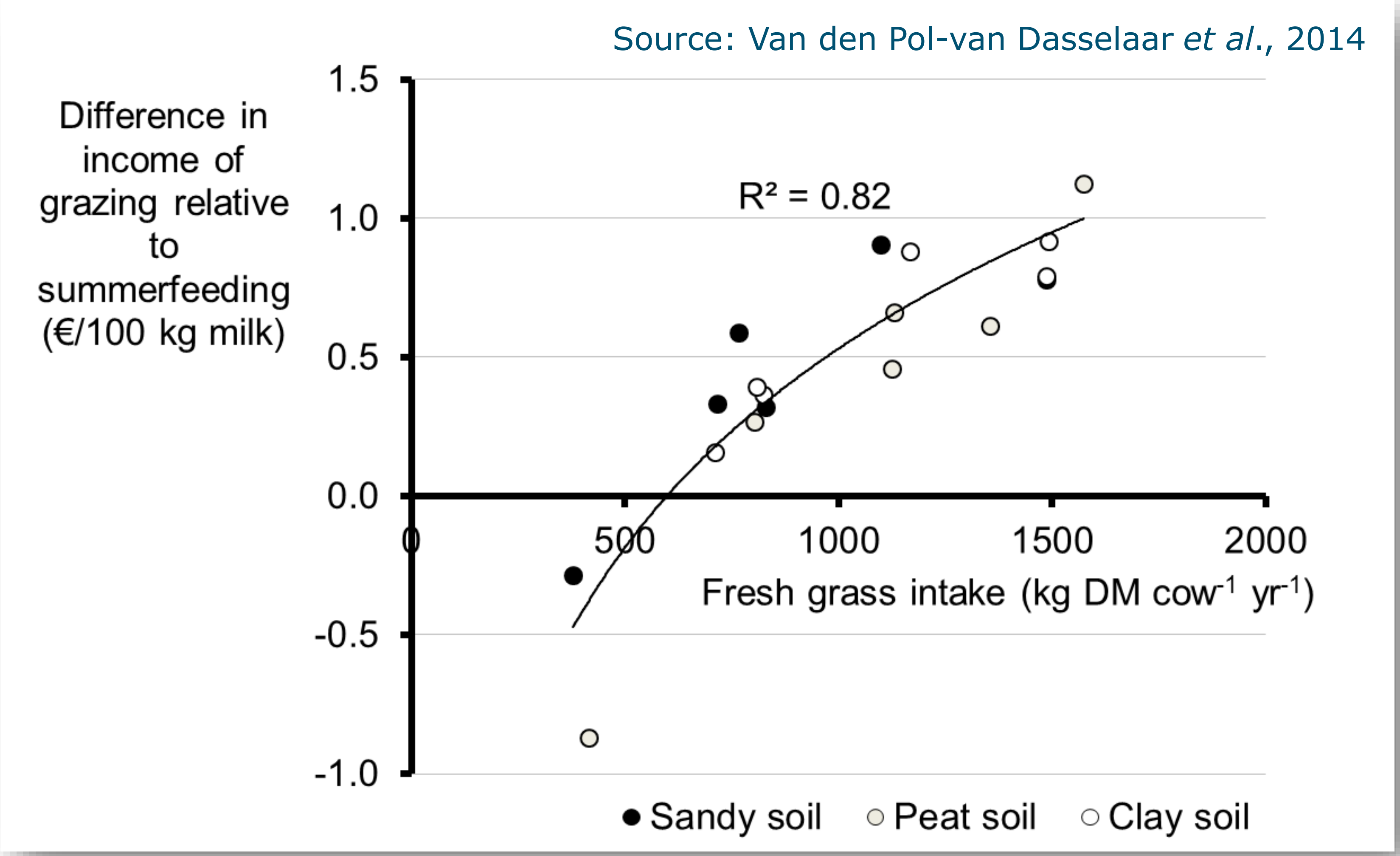
Economy – grass intake crucial factor



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But what about economics under less favourable conditions?

- Aim: to study the economics of grazing and zero-grazing for farms with less favourable conditions for grazing:
  - Automatic milking
  - Small grazing surface (25% instead of 75%)
  - Larger herds (150 animals instead of 75)
  - Higher milk yields per cow (9,500 instead of 8,000)



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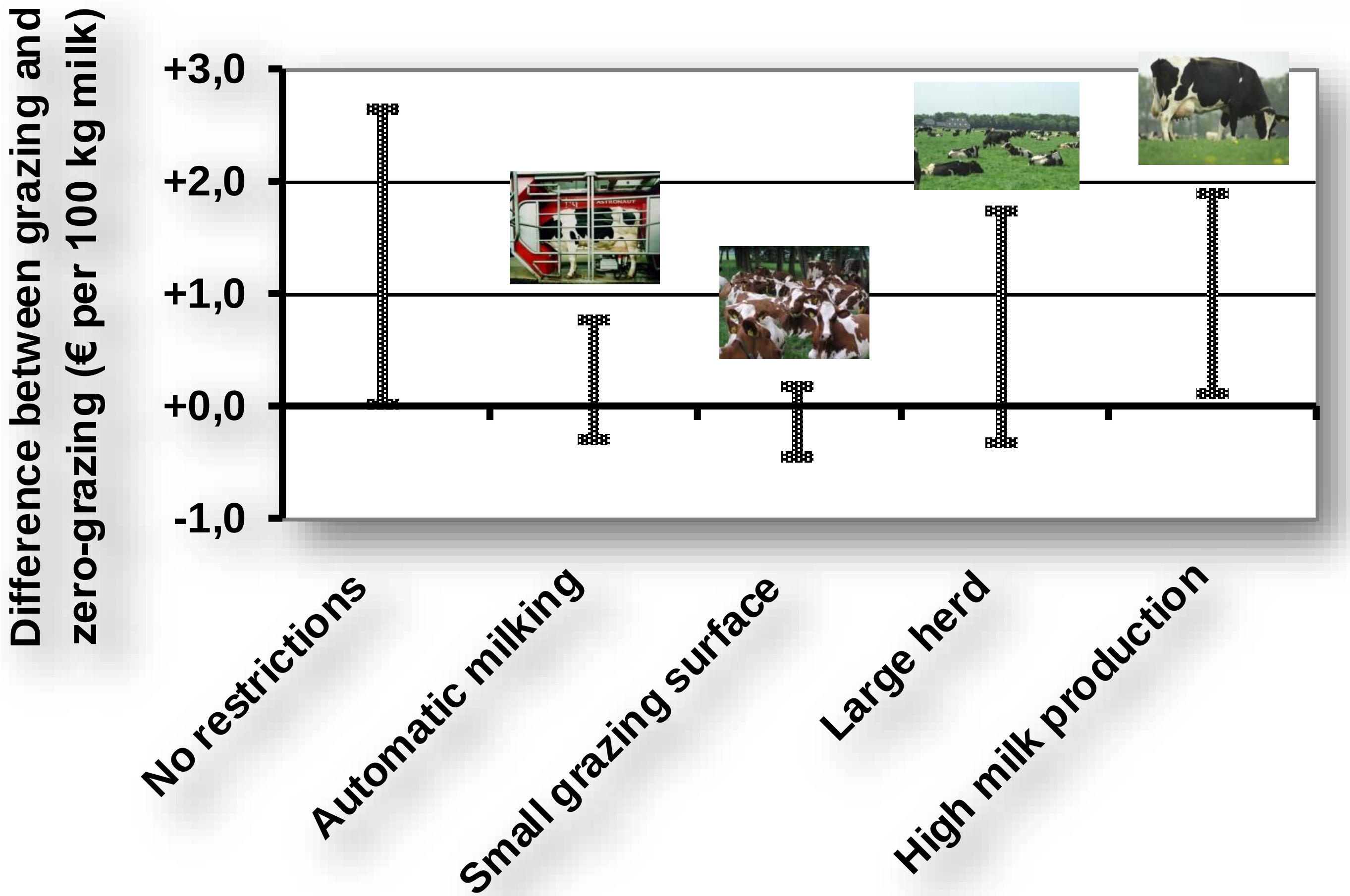
Economics of grazing



Van den Pol-van Dasselaar *et al.*, 2010

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Conclusions

- In general grazing is economically more attractive than zero-grazing
- The only exception is when the available grazing area is too small (grass intake less than 700 kg DM cow^{-1} yr^{-1})
- The more grass the cows eat in the pasture, the larger the income profit
- Economy is not the most important influencing factor for grazing in northwest Europe

- If economy isn't, what is?
  - The Netherlands: on-farm participatory research on 60 dairy farms (Koe&Wij)
  - In the end, personal preferences, experiences and habits of the farmer will be decisive in the choice between grazing and zero-grazing

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How to increase profit?

- Supplementation and grass intake are key factors

- Advisors state: many farms can increase their profit with up to 10.000 Euro
  - Increase grass intake
  - Less supplementation
  - No maize near the farm
  - Optimise grassland management
  - Start early and end late

Cost per kg DM for grazed grass on average 10 ct less than for conserved grass

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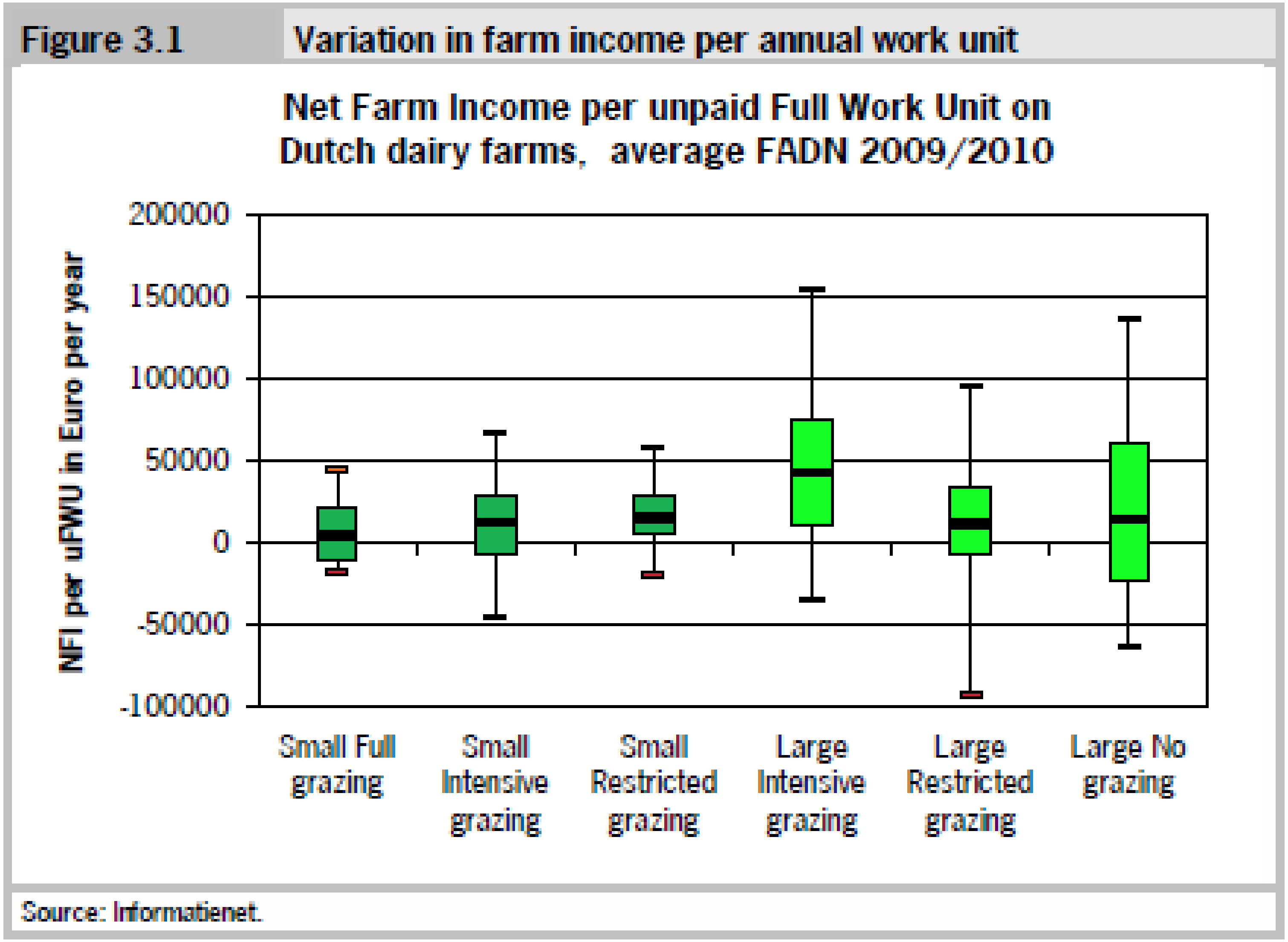
Effect of grazing on farm income (Reijs *et al.*, 2013)



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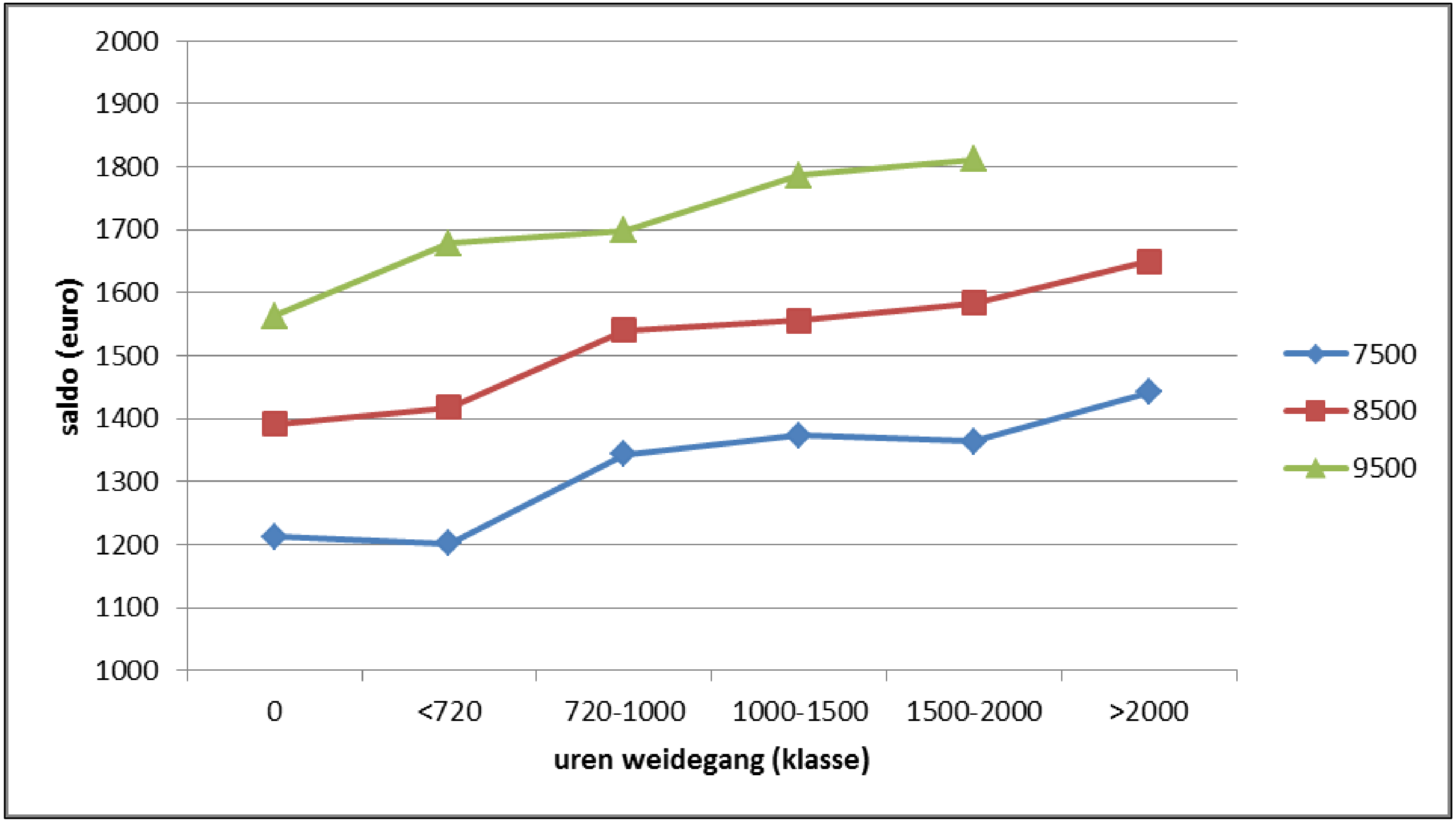
Margin per cow for different grazing hours and different milk productions (Booij, 2015)



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Accountancy data of commercial farms

2013 en 2014: ~ 1000 farms > 4 groups

- No grazing
- 3 groups grazing, with different number of hours grazing per year

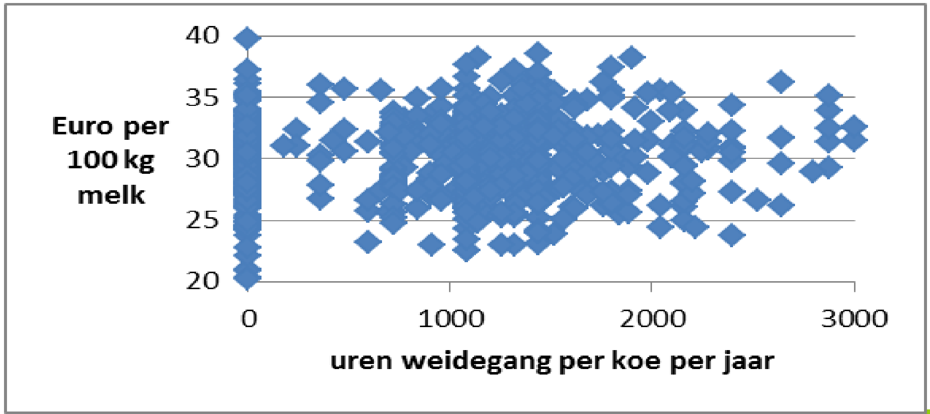
Results 2013

- No effect on milk production per cow
- With grazing: less concentrate costs, more roughage costs (due to lower annual grass production), no effect on total feeding costs
- With grazing: less machinery costs
- On average more € per 100 kg milk with grazing:
  - < 1000: € 0.27 (*not significant*)
  - 1000-2000: € 0.82 (*significant*)
  - >2000 € 0.74 (*not significant*)
  - Note: grazing premium was € 0.50

Results 2014

- Milk yield higher (0.5 ct grazing premium in 2014)
- Less concentrate costs
- Less total feeding costs
- Higher profit

- However: huge variation



Soure: commercial dairy farms Flynth; Van den Pol-van Dasselaar, 2016

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To graze or not to graze

- Trend of decreasing % of dairy cattle with unrestricted stocking in Europe will continue
- Behind this decline are economical, practical and personal motives
- Number of grazing dairy cattle may be influenced by legislation, knowledge transfer and development of relatively simple grazing systems
- Developments in dairy farming, especially increased herd size
- Grazing scores well on the whole
- Personal preference of the farmer determines the grazing system used
- Knowledge on the effect of grazing is affected by personal preferences and experiences
- Preferences may change:
  - With time
  - During major life events
  - Communication with society
- However, there's another important influencing factor next to the elements already described: THE INDIVIDUAL FARMER

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Dilemma: high herbage intake or high utilisation?

- Productivity of dairy cattle is influenced by herbage intake and by nutritive value of the herbage
- Very effective way to increase DMI is to increase herbage allowance
- However, this results in lower herbage utilisation
- Negative effect of higher residuals on subsequent grazings

- Strategies
  - Early grazing
  - Restricted grazing forces the cow to graze more efficiently
  - Leader follower system (high yielding – low yielding or dairy cattle – heifers or sheep)
  - Topping?
- There are opportunities to increase DMI by grazing dairy cows, but they are rather complex

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Tools for measuring grass yield

- Measure
  - Rising plate metre
  - Cutting and weighing
  - Experience
  - Satellites / drones

- **Measure weekly!**

- Several types of rising plate metres
  - Manual
  - Automatic
- https://www.youtube.com/watch?v=9zp8PRConnM

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Legislation: Nitrates directive and Dutch Action Programme

- Max 170 kg N from animal manure per ha related to leaching (Nitrates directive)
- Netherlands: higher N uptake due to good climate conditions -> derogation up to 250 kg N (in situations of at least 80% grass)
- Fertilization standards have been defined
- Grassland based systems max. 250 kg N/ha
- Max. active N/ha: from organic and synthetic fertilizer: 320 - 250 kg/ha, depending on soil type and grazing
- Limitations on phosphate application, no distinction between organic and synthetic fertilizer
- High output dairy farming systems in the Netherlands characterised by high fluxes of N and P
- Research to avoid losses to the environment and to increase production efficiency
- Insight into the flow of minerals at farm level
- Practical tools for farmers, e.g. ANCA (Annual Nutrient Cycle Assessment)
- From 2015 onwards, ANCA as licence-to-produce

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Farm Specific Excretion (BEX)

- Apply standards: easy to use, manure export is known

- Using Farm Specific Excretion BEX:
  - Ministry of Economic Affairs gave an opening
  - Challenge: calculate farm specific excretion of N and P
  - System is evidence based, transparent, maintainable

- Stimulates farmers to improve their nutrient efficiency

- Explanation:

https://www.youtube.com/watch?v=1cnERj9fooc

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'New' fertilisers

- Liquid fertilizer
- Digestion of slurry
- Dividing manure in a solid (mainly P) and a liquid component (mainly N)

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FarmWalk®

- Weekly tour through the fields
- Individually and in groups
- Look, measure, decide, do
- Informed choices for the coming days, weeks, months

FarmWalk®

farmwalk®
grip op gras

Tool voor dagelijks management van grasland en beweiding met als basis een wekelijkse ronde door het eigen gras

Doe de FarmWalk®

- Result: in control

Grazing Coaches

- Grazing Coaches train dairy farmers in FarmWalk®
  - several meetings during the growing season, groups of 10 persons
- They are trained themselves

received funding from the
0 research and innovation
nt agreement No 727368.

Development FarmWalk®

2014

- 13 + 32 Coaches
- 400-500 Farm Walks

2015

- 45 + 30
- 500 + 1000

2016

- 75
- 1500 + 1500

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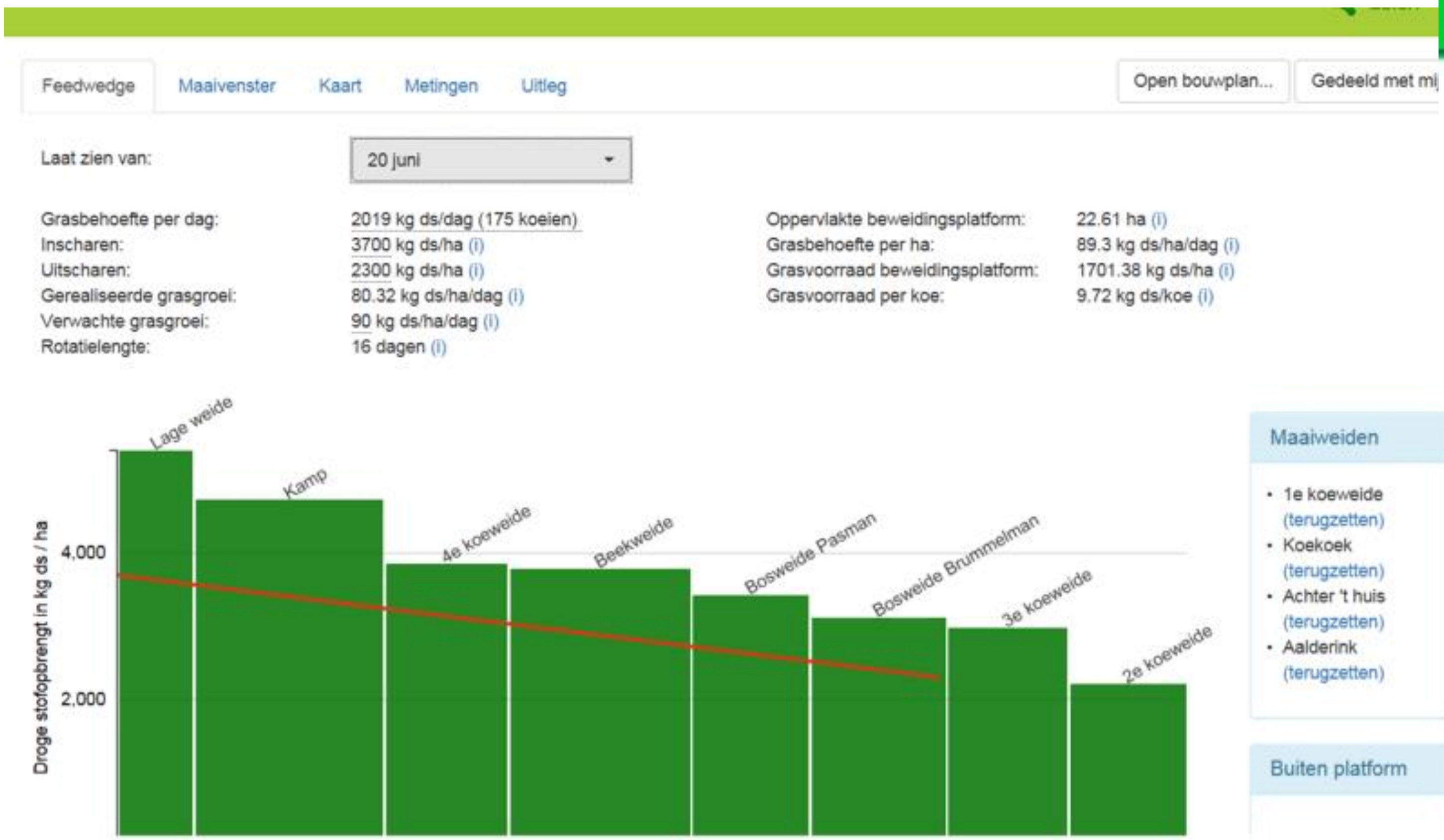
Grip op Gras: tool for FeedWedge



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Pasture grazing advices from farm task groups

1. There is a grazing system that suits you

   Where there’s a will, there’s a way of grazing

2. A good pasture manager is a flexible pasture manager

   After all, we are all facing the same weather,
   aren’t we?

3. Go with the flow; the cow is the boss

   A healthy cow has its own rhythm

4. Urea can definitely be influenced

   Less manure and more forage works miracles

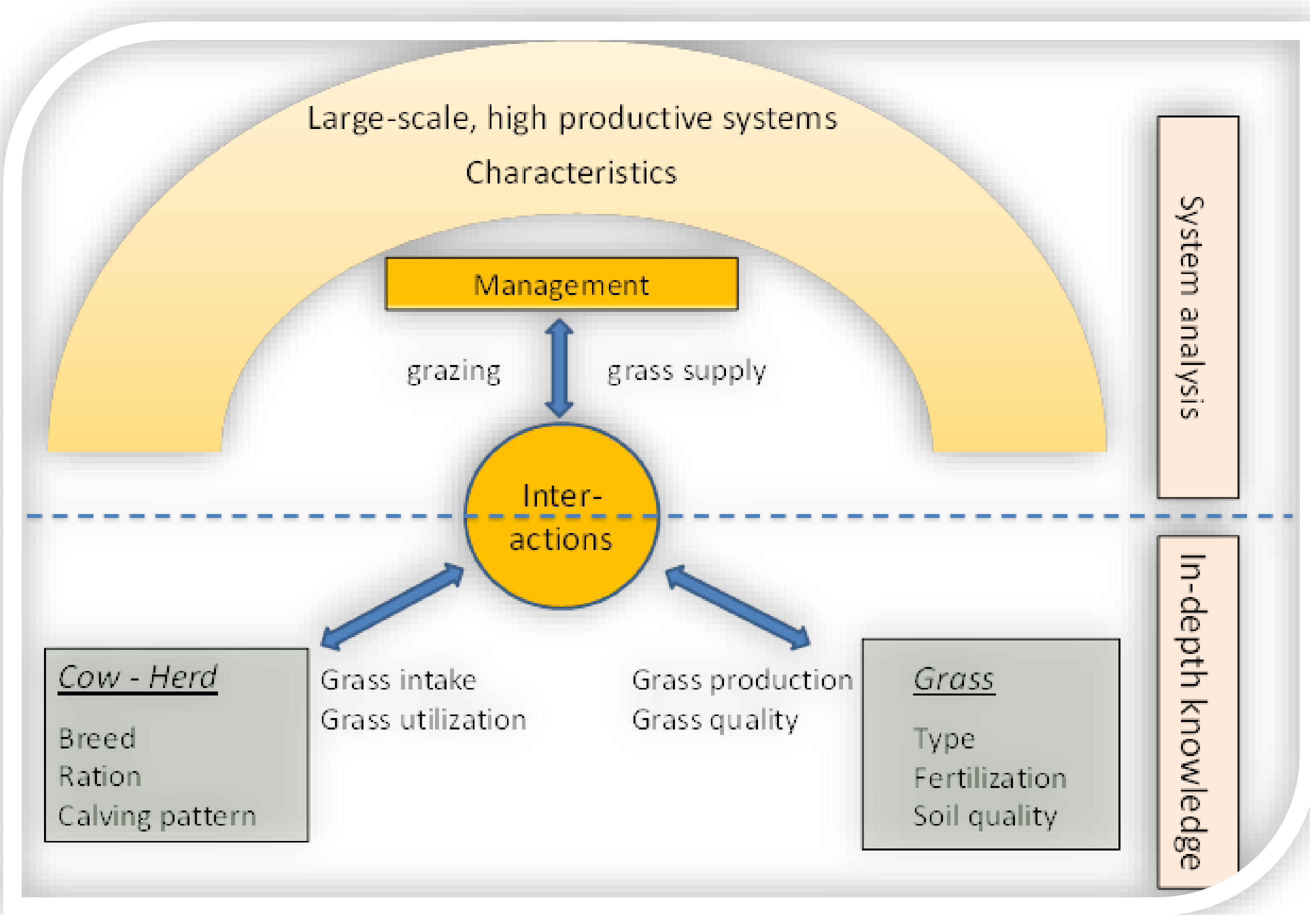
5. Mowing as an instrument in grazing

   More taste due to mowing

Practical advise: grazing and large herds

- Just do it!
  - What is a large herd?
- Everything larger...
  - effects also..
- Cow routing, water supply
- Enough grass allowance
- Divide the herd...
  - High and low yielding, age, lactation stage
- Short rotation in situations of trampling
- No chasing, cows should set the pace

Innovations & Research topics in NL



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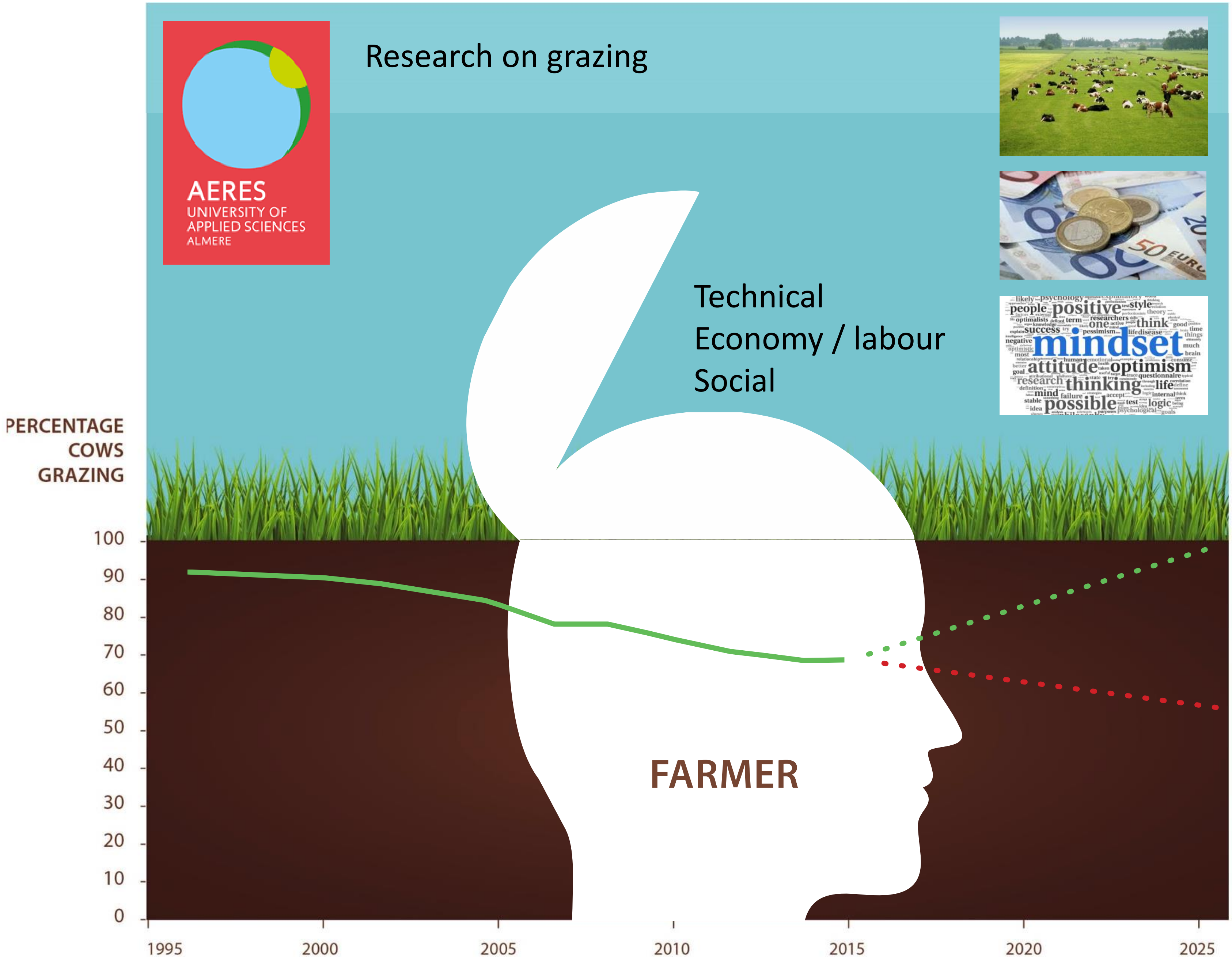
AERES
UNIVERSITY OF
APPLIED SCIENCES
ALMERE
Research on grazing
Technical
Economy / labour
Social
PERCENTAGE
COWS
GRAZING
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2020
2025
FARMER
people
positive
style
think
success
mindset
attitude
optimism
research
thinking
life
mind
possible
logic

Mobile milking

- Perspectives for
- Land on large distance from barn
- Partial grazing large herd
- Nature farming

- Research themes "Natureluur" (NL)
- (2008-2010)
- Technical development of this innovation
- Explore grazing systems with 'Natureluur'
- How will cows behave?
- Optimize cattle management

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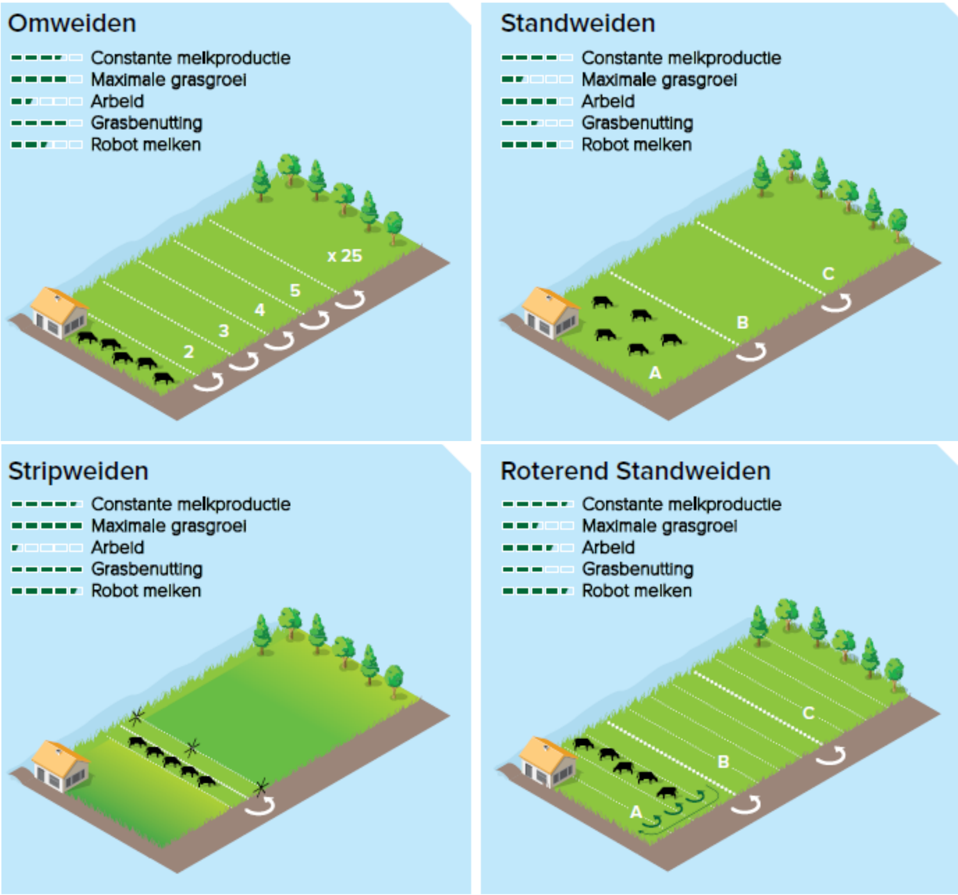
Dynamic grazing; Choose the right grazing system

- Choose the system that fits...
  - your farm and
  - your preferences
- E.g. maximum grass growth and grass utilisation: strip grazing, rotational grazing
- E.g. minimum labour: continuous grazing



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Robot and grazing

- See brochure (in Dutch): http://www.stichtingweidegang.nl/images/RobotenWeiden/Eindproducten/RobotWeiden_Concepten_102015.pdf

Weidegang
LIVESTOCK RESEARCH
WAGENINGEN UR

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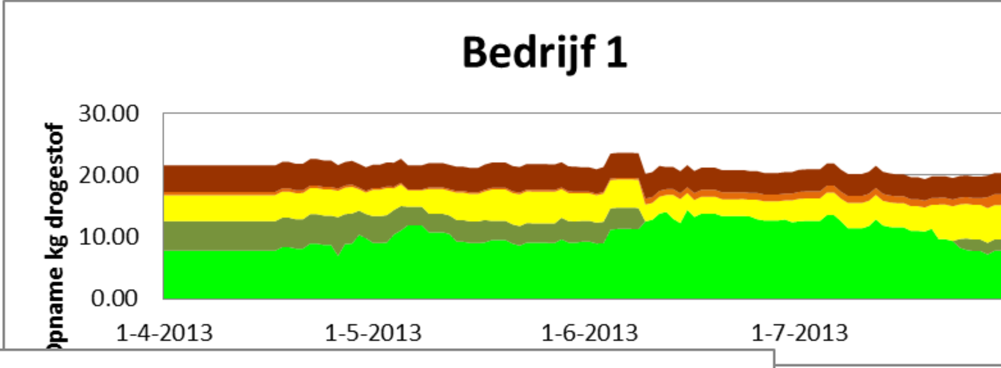
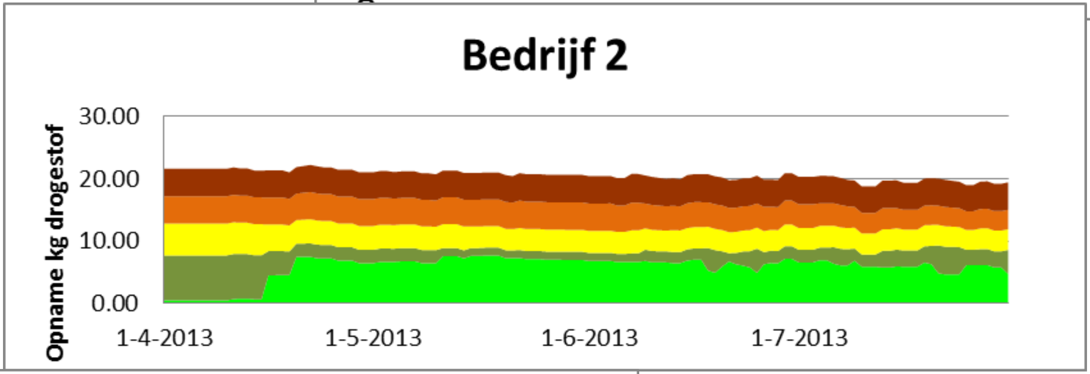
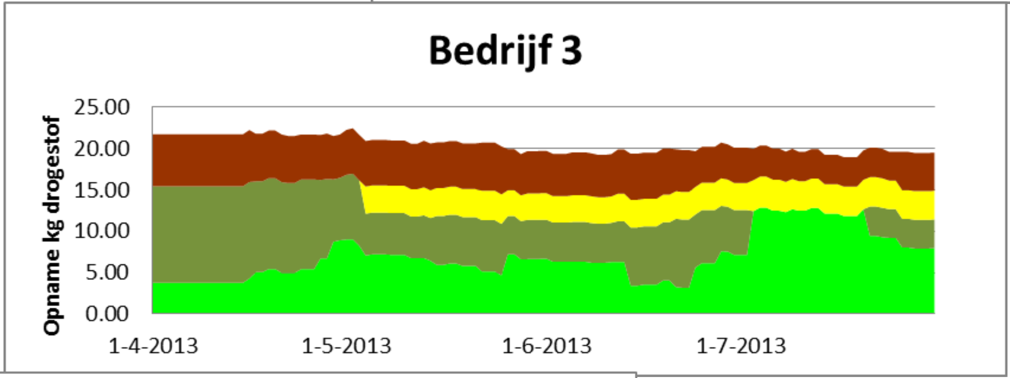
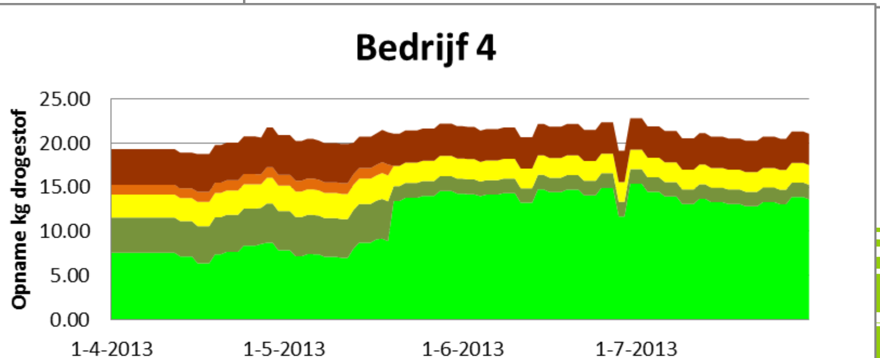
Tools; Fresh grass dashboard Summer 2013









Kg DM intake per day from:
- Concentrate
- Others
- Maize silage
- Grass silage
- Fresh grass grazing

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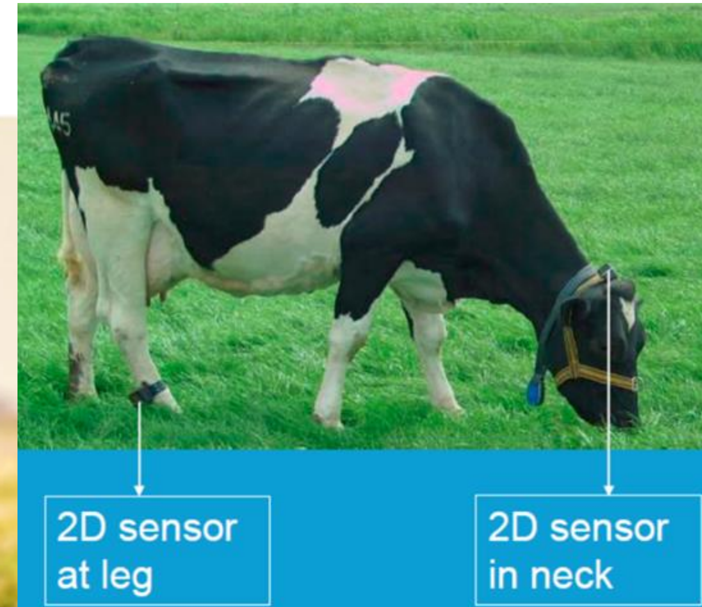
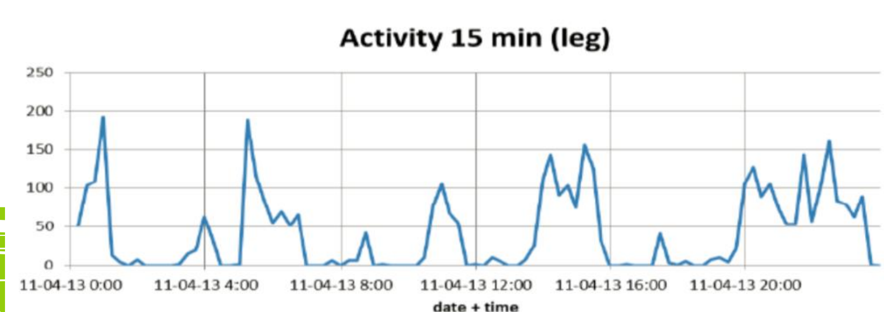
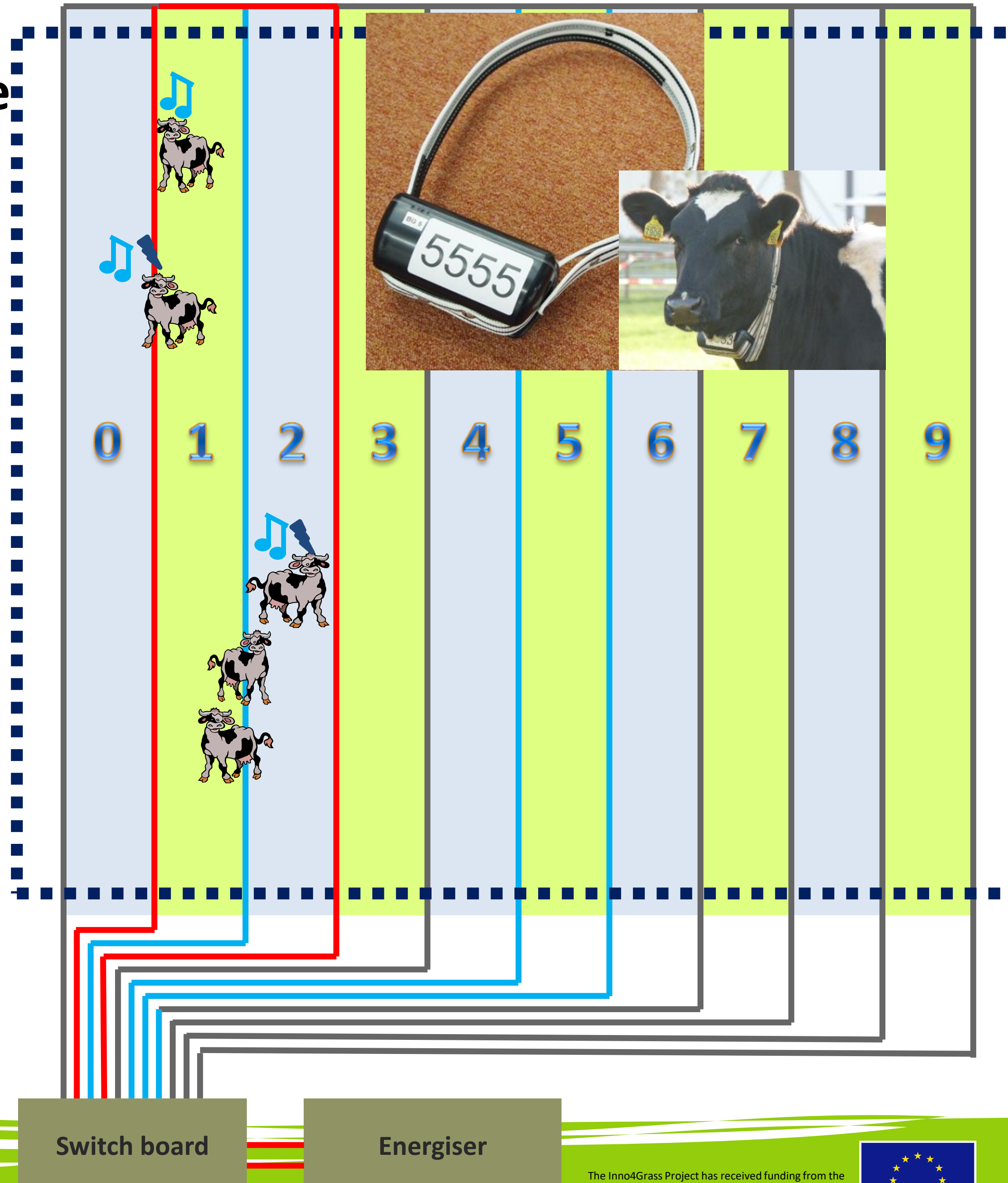
Sensor data – grazing time



- Sustainability



Innovation: Virtual fence



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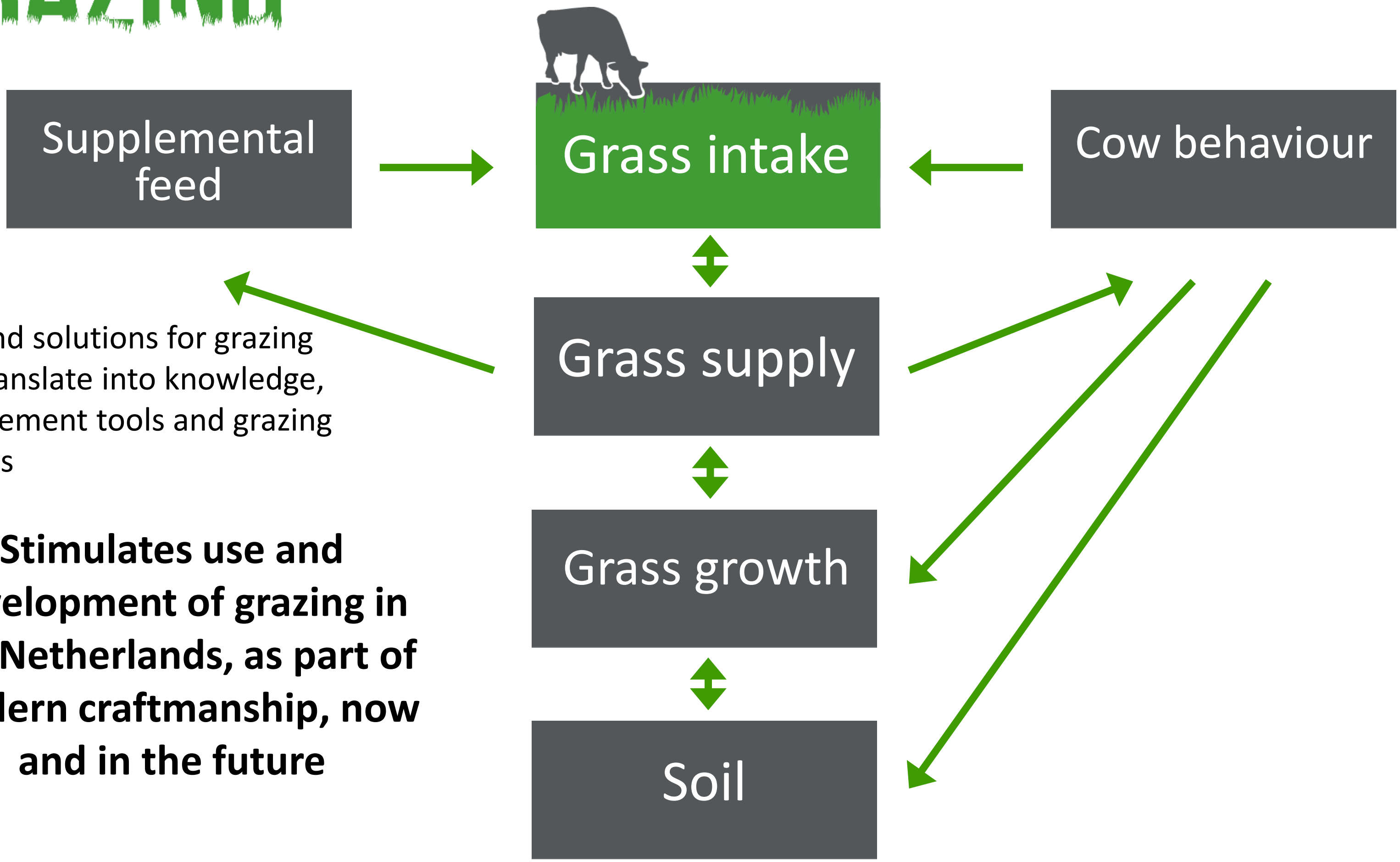
Building blocks grazing



- To find solutions for grazing
- To translate into knowledge, management tools and grazing systems

Stimulates use and development of grazing in the Netherlands, as part of modern craftmanship, now and in the future

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Belgium

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Temperate legumes: key-species for sustainable temperate mixtures of Belgium

- **Peeters A.[1], Parente G.[2] and Le Gall A.[3]**
- ***[1]Unit of Grassland Ecology, UCL, Belgium***
- ***[2]ERSA, Italy***
- ***[3]Institut de l'Elevage, France***

Renewed interested in forage legumes

- **Recent European research programmes:**
  - LEGSIL 'Legume Silages for Animal Production' 1997-2001
  - LEGGRAZE 'Low input animal production based on forage legumes for grazing systems' 2001-2005
- **European research network:**
  - COST action 852 'Quality legume-based forage systems for contrasting environments' 2001-2006

Species

- **White clover (*Trifolium repens*)**
- **Red clover (*Trifolium pratense*)**
- **Lucerne (*Medicago sativa*)**



Secondary species

- **Sainfoin (*Onobrychis viciifolia*)**
- **Birdsfoot trefoils (*Lotus* spp.)**
- **Alsike clover (*Trifolium hybridum*)**
- **Galega (*Galega orientalis*)**

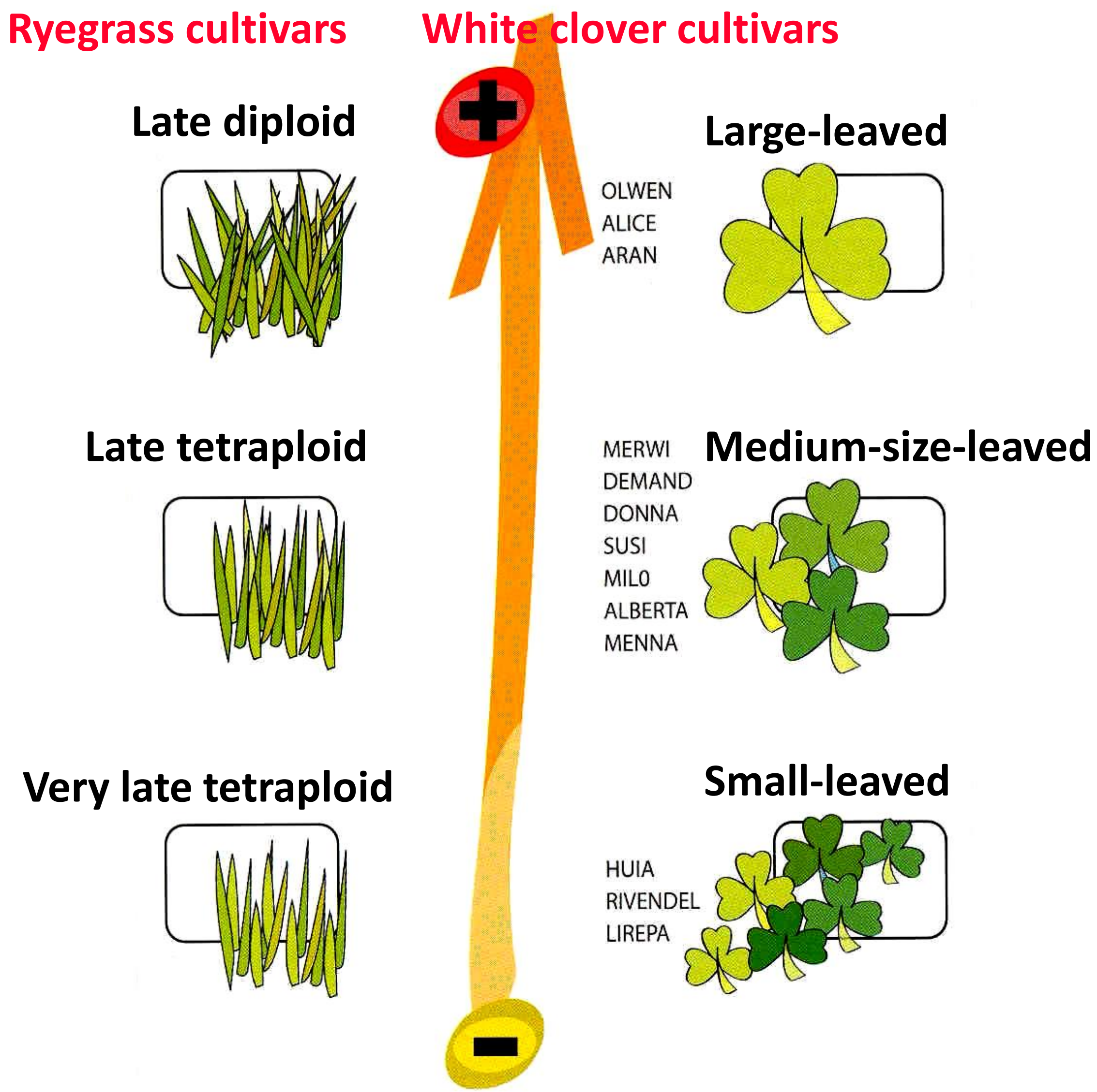



Novel species

- **Caucasian clover (*Trifolium ambiguum*)**

Legume-grass mixtures

Compatibility between cultivars of two species



Annual Production White Clover

- **White clover in pure stand:**

  about 6-9 t DM ha^{-1}

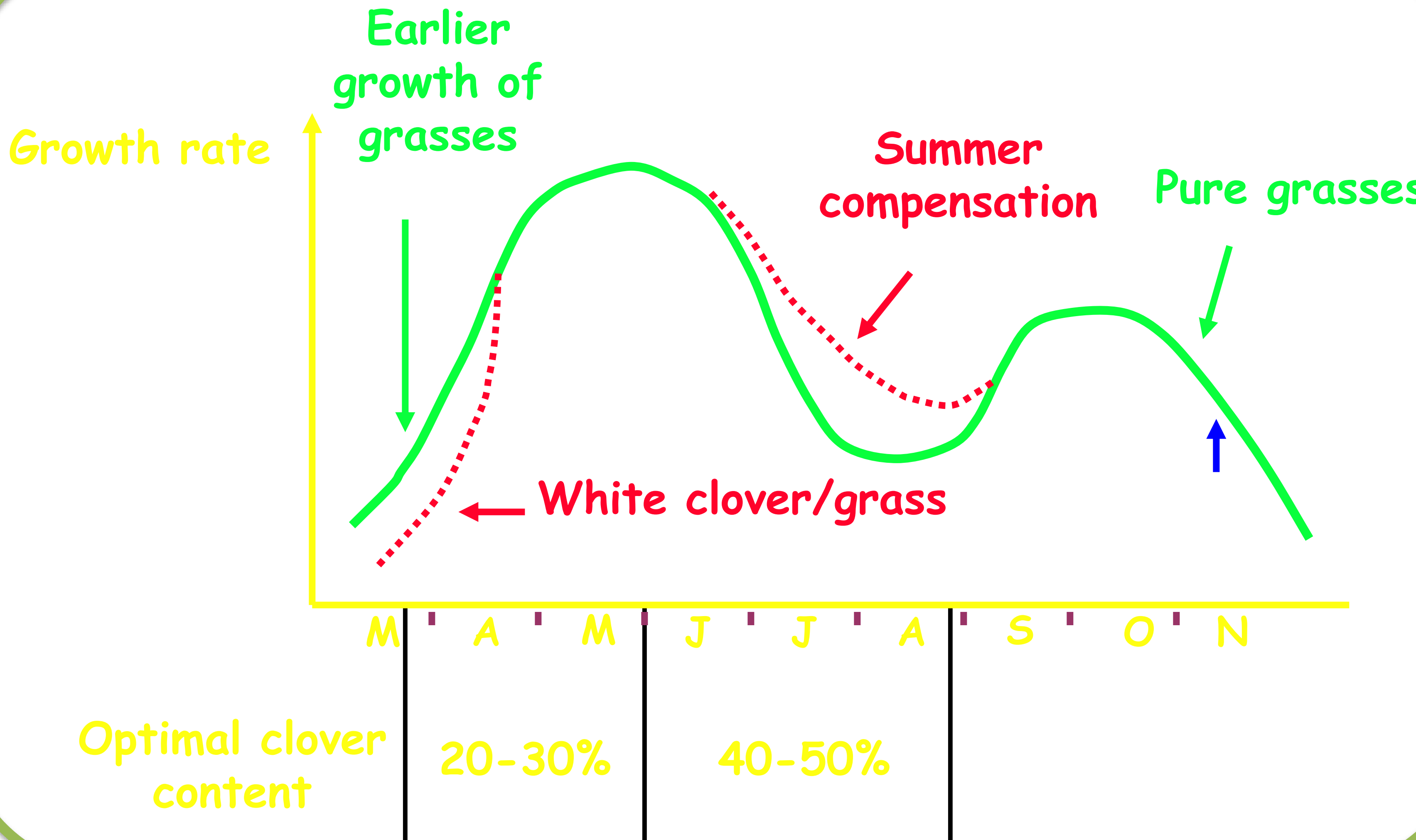
- **White clover/grass mixtures in good conditions in the west of Europe:**

  7-11 t DM ha^{-1} and up to 20 t DM ha^{-1}

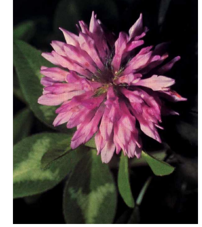
- **In the north of Europe, mixtures:**

  about 6-8 t DM ha^{-1}

Production White Clover



Production Red Clover



Red clover is higher yielding than white clover

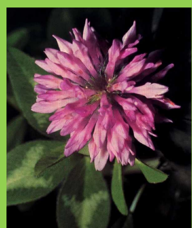
Table 1. Typical annual yields (t DM ha^{-1}).

	A1	A2	A3
Pure red clover swards			
West of Europe	10-14	7-10	3-4
South of Europe	13-21	6-13	-
North of Europe	7-8	7-8	-
Red clover/grass mixtures			
West of Europe	11-17	8-15	-
North of Europe	6-9	7-9	5

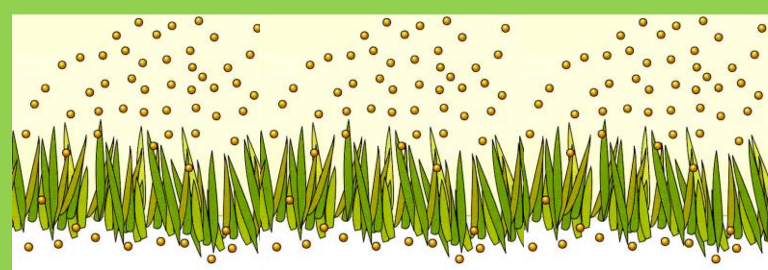
A1: first production year; A2: second production year; A3: third production year

Yield (t DM/ha)

Red clover/grass mixture yield



N-fertilized grass yield



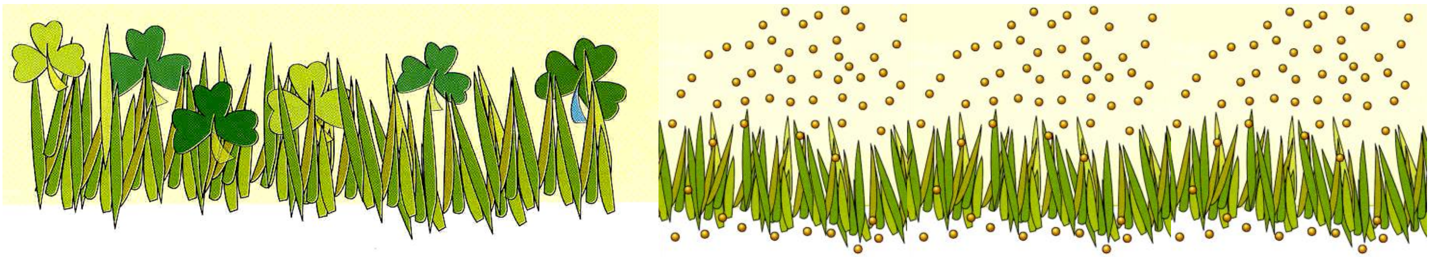
N fertilizer (kg/ha)





	Annual yield (t DM ha^{-1})
Sainfoin	7-15
Birdsfoot (monoculture)	5-7
Alsike clover	red/white clovers
Galega (monoculture or mixture)	8-10
Caucasian clover	? in Europe

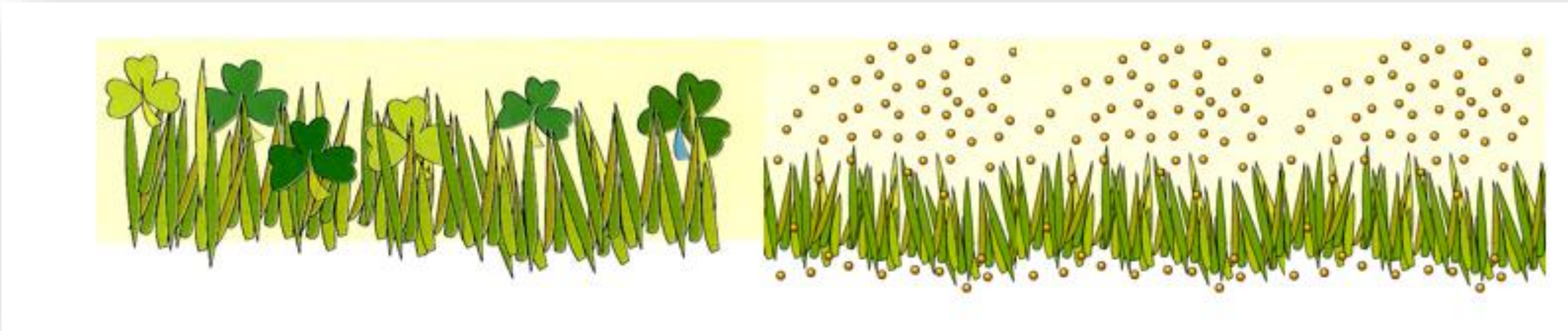
Nutritive value, voluntary food intake, animal performance



Legumes **grasses:**

- **higher digestibility, crude protein (CP), pectin, lignin, ash, Ca and Mg contents**
- **poorer in total cell wall or neutral detergent fibre (NDF), hemi-cellulose and water-soluble carbohydrate (WSC)**
- **nutritional superiority and higher intake characteristics**

Nutritive value, voluntary food intake, animal performance



Legumes ⟷ grasses:

- High protein content in legumes can also be a problem
- Inefficient use of protein in the rumen can lead to high levels of N-based pollution

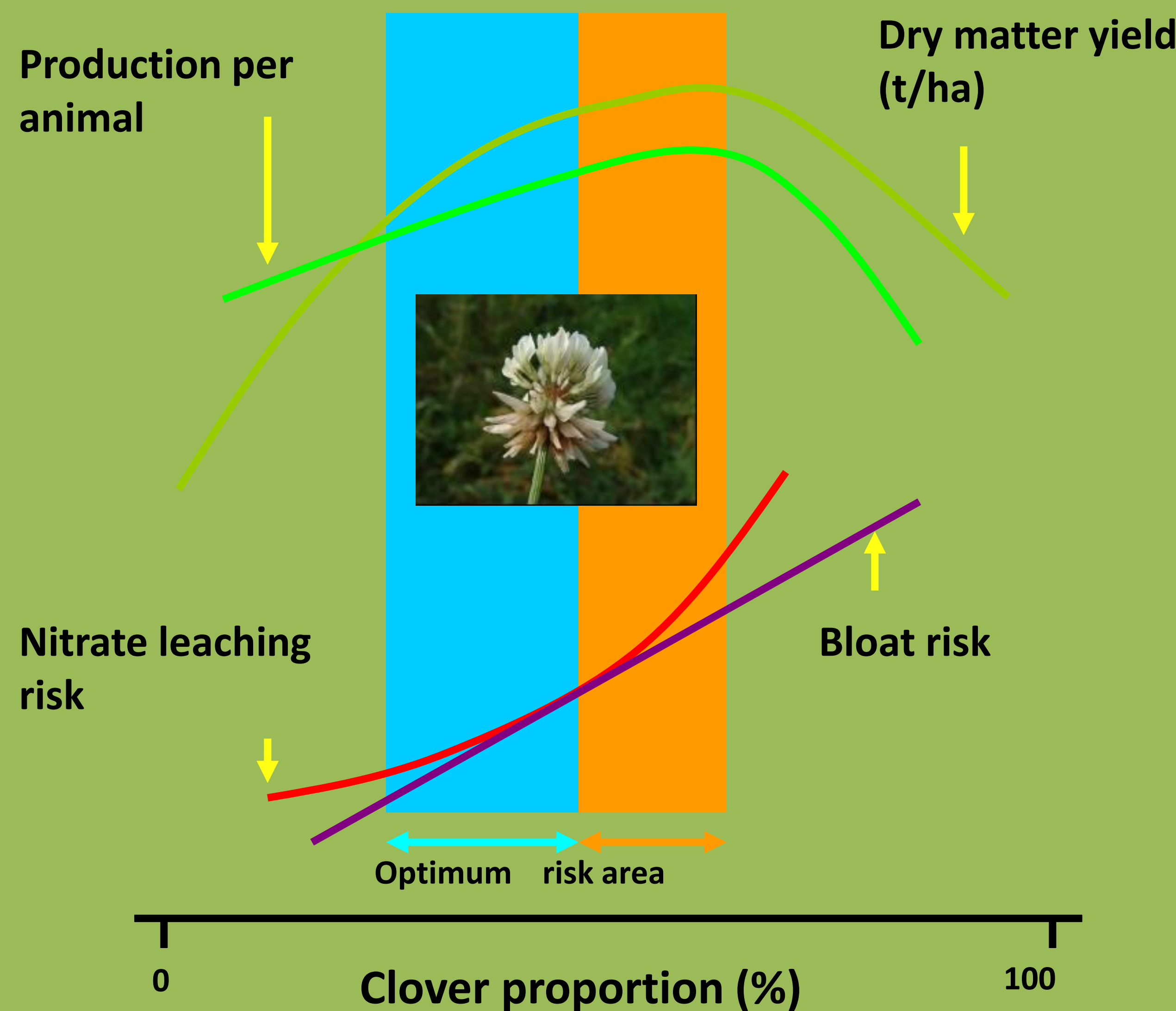
Nutritive value, voluntary food intake, animal performance

- High protein content: reduced proteolysis can be a way to solve the problem

- Sainfoin and birdsfoot trefoils: Condensed tannins reduce the degradation of the main leaf protein (Rubisco) and to a lesser extent its solubilisation in the rumen
- More non-ammonium nitrogen is thus supplied to the small intestine

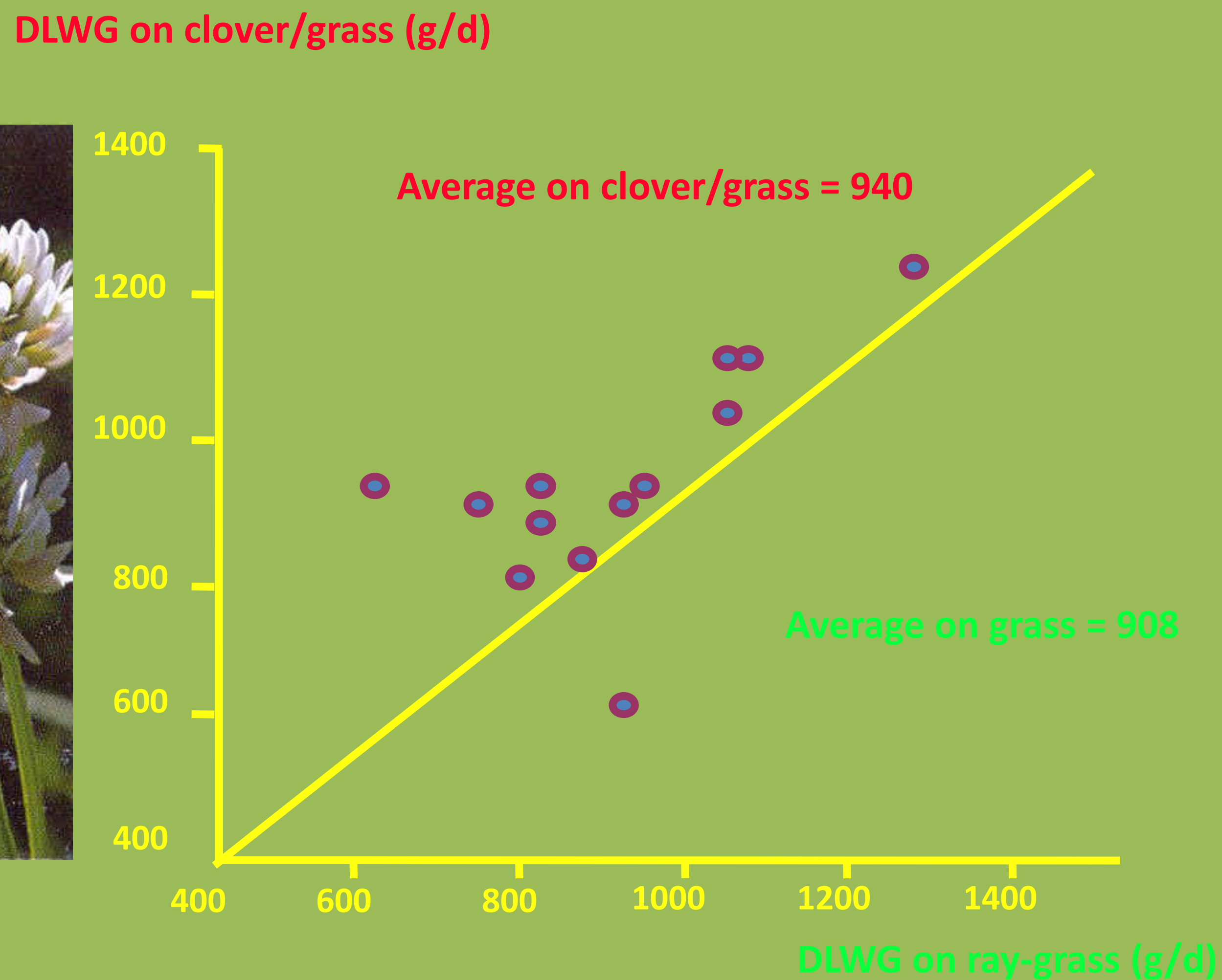
- Tannin contents at 20-40 g kg^{-1}: better efficiency in N utilization, prevent bloat and reduce the negative effects of internal parasites in sheep

Target: 40-50% white clover in summer



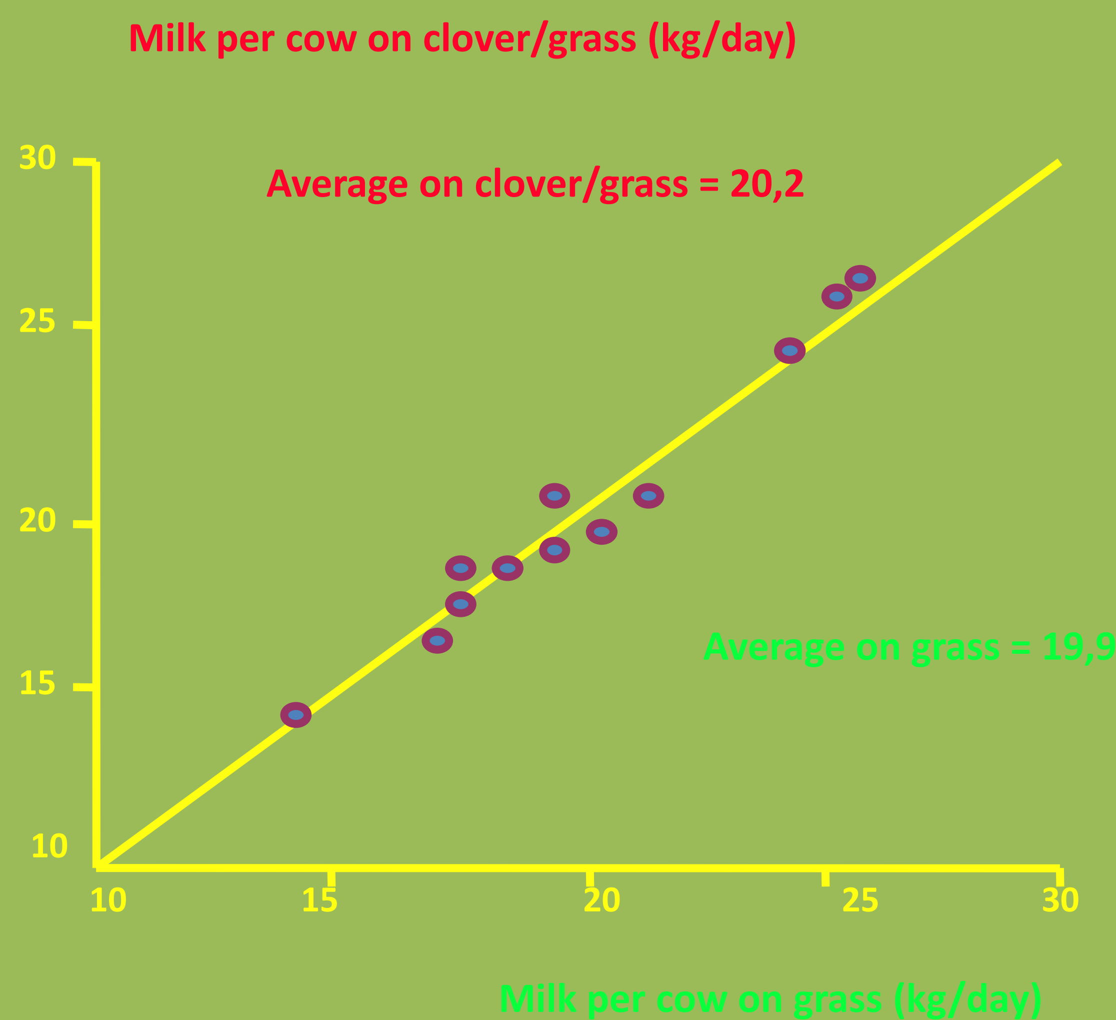
Source: Pfimlin, 1993

Meat production



Source: Institut de l'Elevage, 1993

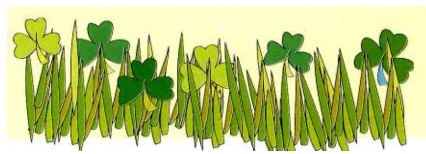
Dairy production

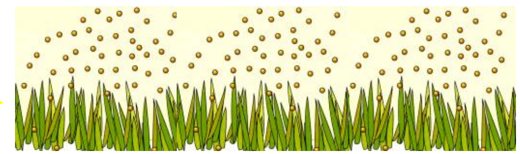


Source: Pflimlin et al., 1993

Nutritive value, voluntary food intake, animal performance

In silage
Red clover/grass

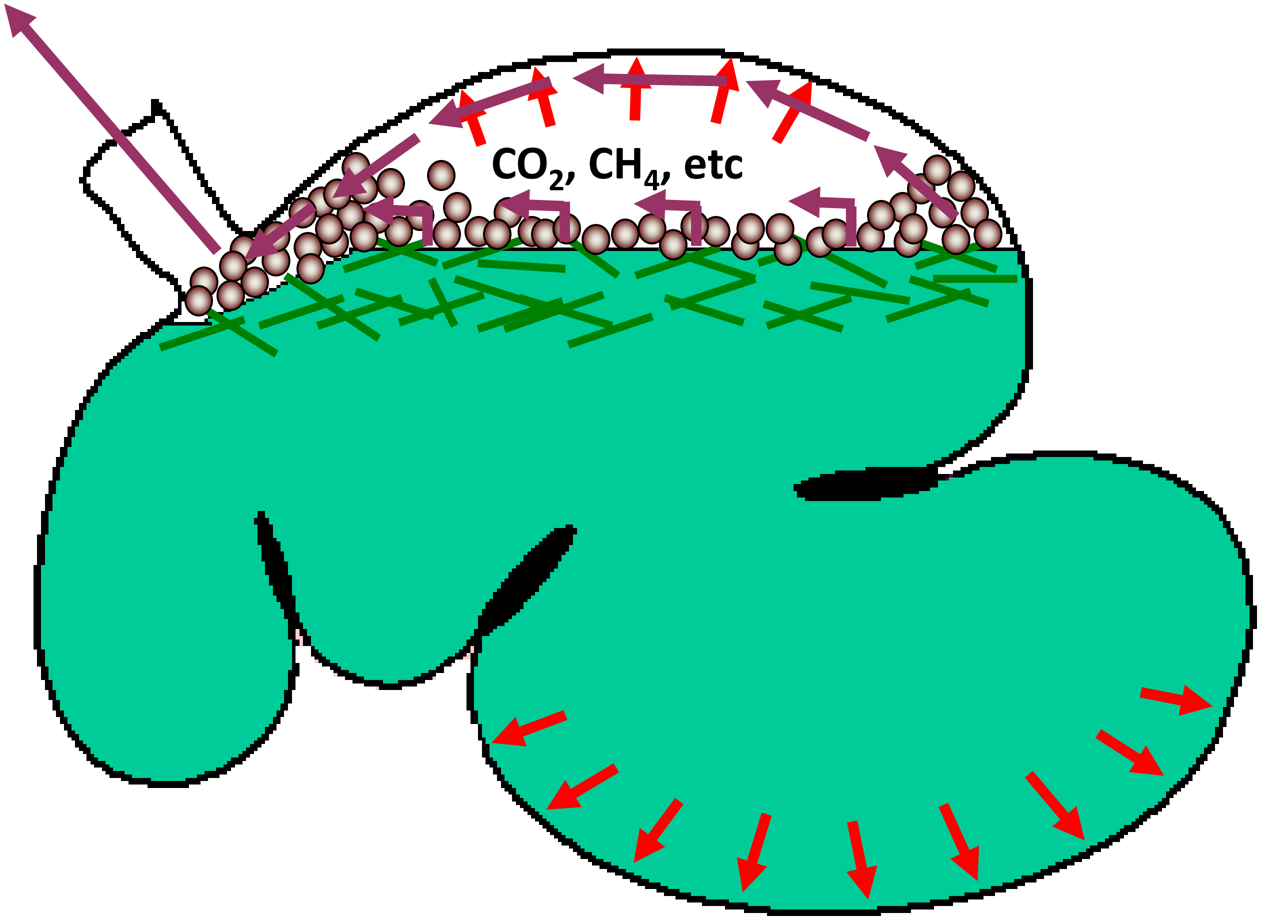




- Similar energy contents and higher crude protein contents
- Better energy utilization and better energy gain
- Better intake for similar digestibility
- Better animal performance in beef production and in dairy cows

BUT
a part of the nutritional advantage of legumes can be reduced by leaf losses during the wilting and harvesting processes.

Bloat in cattle (and in sheep)
Occurrence low: < 0.8% per year



Anti-quality factors and other secondary metabolites

Cyanogenic glucosides in some cultivars of

 and 

(asphyxiation in grazing animals). Levels generally low.

- Significant infertility problems in sheep grazing because of phyto-oestrogens.
- Cattle are less susceptible.
- Cultivars with a low content are increasingly available.

Anti-quality factors and other secondary metabolites

- Flavonoids as well as fatty acids can affect the chemical and sensorial properties of sheep (Cabiddu *et al.*, 2001) and cow (Bertilsson *et al.*, 2002) milk

- Some forage legumes could increase the milk polyunsaturated fatty acid concentration and affect in a pleasant way the flavour of milk and cheese

- BUT oxidation products of polyunsaturated acids, such as *n*-aldehydes and peroxides, can produce bad flavour in dairy products (Rochon *et al.*, 2004)

Nitrogen fixation

- Transfer of N from legume to grass can occur in three ways:
  - exudation of low molecular weight organic-N compounds
  - degradation of senescent legume organs (nodules, roots, leaves and stems)
  - excrements of grazing livestock, especially urine

- The second and the third route are the most important in grasslands

- Underground transfer is 25-50% of the total (Ledgard, 1991)

- Proportion of N fixed transferred to grasses highly variable:

13 to 34% (Heichel and Henjum, 1991)

Nitrogen fixation

- Several types of assessment methods:
  - Nitrogen yield difference (NYD)
  - Nitrogen Fertilizer Replacement Value (NFRV)
  - Acetylene reduction
  - N^{15} isotope-based methods

- All these methods have disadvantages and none is totally reliable

- Some of the isotope-based techniques may be more precise

Nitrogen fixation

Typical values (kg N/ha.year)

White clover: 100-300

Red clover: 200-400

Birdsfoot trefoil, maximum: 140

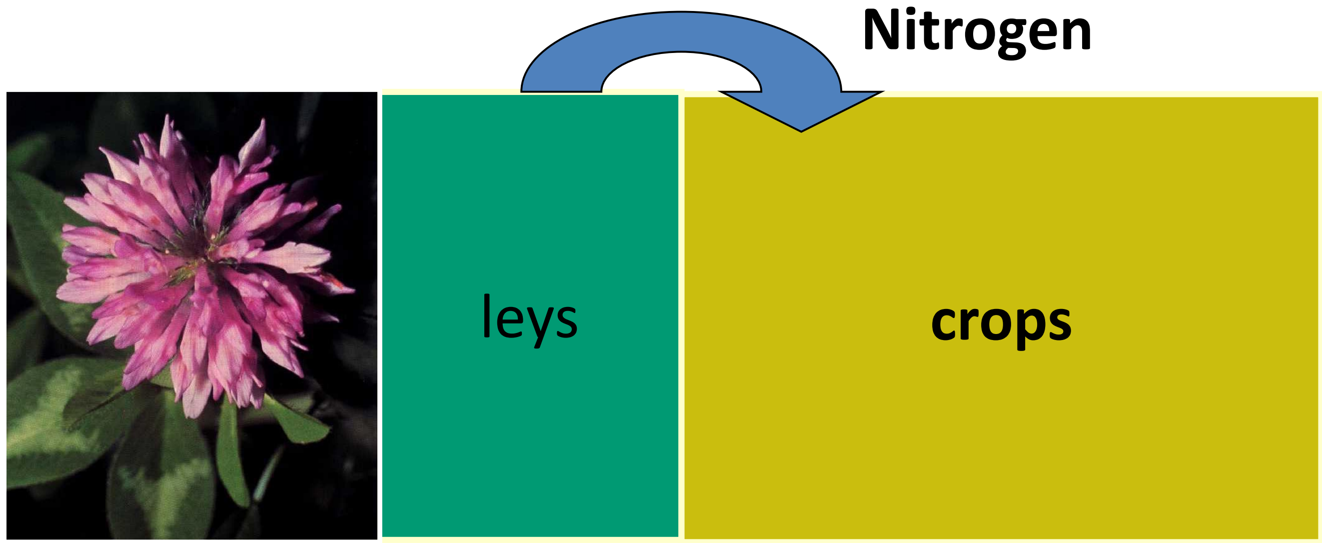
Sainfoin: can be very low

The amount fixed is proportionate to the legume content of the sward:

	N (kg) fixed per t of DM
White clover	30-46
Red clover	24-36

Nitrogen fixation

N transfer in grassland/crop rotation with red clover



Leys

About 6O kg N ha^{-1} for the subsequent crop

Land set-asides

80-160 kg N ha^{-1} for the following crop

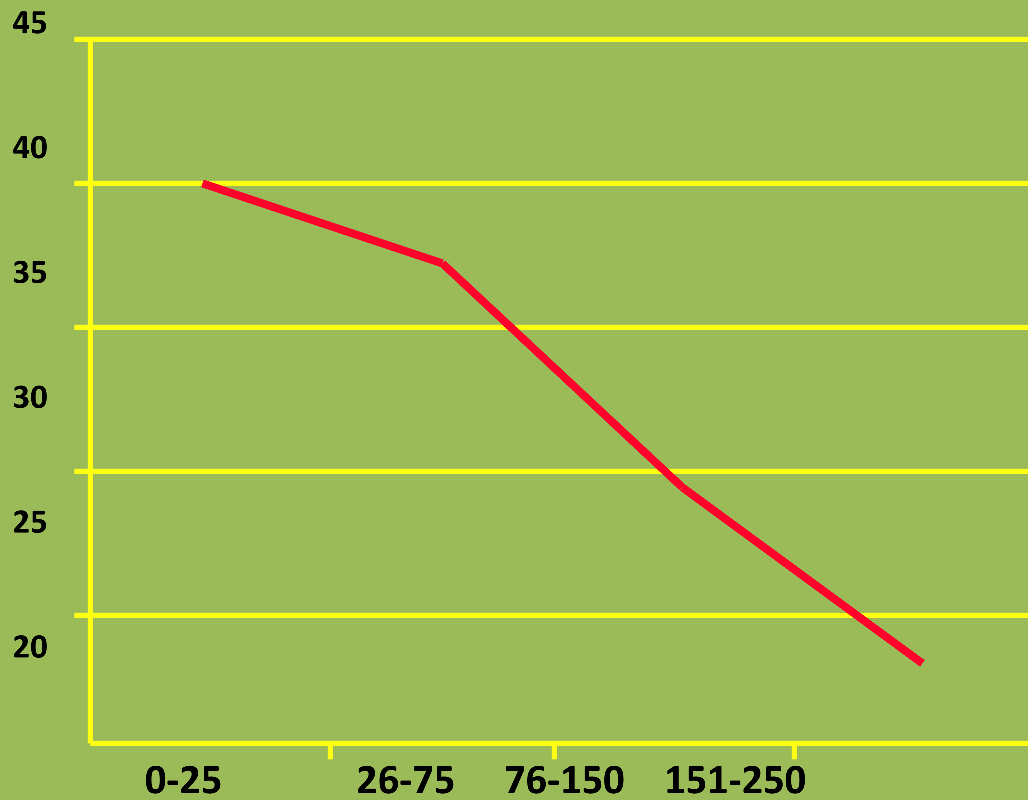
after legume/grass mixtures

160-260 kg N ha^{-1} after pure legume swards

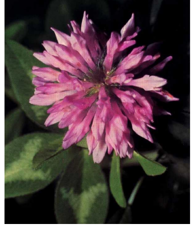
Utilization of white clover

Factors		
N fertilizers	0 N	High N
Period of N application	late summer and autumn	Spring and early summer
Type of N fertilizer	Organic	Inorganic
Type of animal	Cattle	Sheep low branching, thin short internodes of stolons, small leaf size, reduced WSC content of stolons
Period of sheep grazing	Autumn and early spring	Rest of the year
Defoliation interval	Frequent (grazing)	Infrequent (cutting)
Cutting system	Early (silage)	Late (hay) far red/red light ratio high: stolon branching and number of growing points reduced
Grazing/cutting combination	Interposed silage cut (restoration of stolons)	Trampling (harm stolons)
Grazing system	Rotational	Continuous

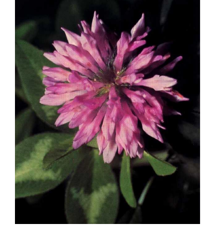
Clover proportion in summer (%)



Annual nitrogen fertilisation (kg N/ha)



Utilization of red clover



- Adapted to infrequent defoliation and thus to conservation
- Leaf losses increase with increased wilting: higher for hay than for silage
- Dry matter losses at harvest: 14% to 45%
- Leaf loss can be minimized by:
  - reducing the number of times hay is handled
  - handling hay at high humidity
  - using hay conditioners
  - using clover/grass mixtures

Utilization of red clover

- Despite
  - low WSC
  - high CP contents
  - high buffering capacity
- Can be successfully ensiled if wilted
- Use of an additive can help
- Mixing red clover with grasses

Environmental issues in legume-based system

- Legume-based systems have genuine advantages for the efficiency of N use compared with those based on inorganic N fertilizers:
  - excess of N supply is avoided
  - ammonium form is more abundant in the available soil N pool
- In farm conditions, nitrate leaching losses smaller but stocking rates are usually lower too

Environmental issues in legume-based system

- Release similar amounts of nitrate at comparable levels of animal production per hectare

BUT

- Leaching in a clover/grass system relative to a 200N grass system varied from 50% to less than 30% (Ledgard *et al.*, 1999)

- Nitrate leaching after ploughing of clover leys: spring ploughing instead of autumn ploughing

Environmental issues in legume-based system

Reduction of fossil energy
(synthesis of inorganic N fertilizers)

Pimentel et al. (2005) compared a conventional cash-grain system with a typical livestock system (legume-based ley + crops)

Fossil energy inputs: about 30% lower in the second system

Environmental issues in legume-based system

- Good source of pollen and nectar for some insect species
- Flowers are attractive for the landscape
- Many legume-based swards are too dense for birds that cannot use them as a breeding and a feeding cover
- Lucerne is a notable exception: permeable to bird circulation and provides arthropods and nutritious leaves, a shelter against predators and a good nesting place if cut late

Conclusions and prospects

- Two main attributes for future agriculture that reduces production costs and increase farmers' income:
    - capacity for N fixation
    - high nutritive value and intake potential

- In extensive systems: reduce N fertilization while maintaining sward yields at an acceptable level

- One of the pillars of organic systems

Conclusions and prospects

- Main shortcoming: lack of persistence

- Grazing: occurrence of bloat should be minimized by the introduction of the genes of CT synthesis within the genome of clovers BUT consumer’s acceptance!

- Conservation: development of techniques that can minimize leaf losses and control buffering capacity, ammonia content and development of undesirable micro-organisms

Conclusions and prospects

- Main positive effect of legumes for the environment: reduction of fossil energy use and the emission of CO_2 to the atmosphere
- Control of N emissions from legume-based systems
- Future research: N fixation and utilization efficiency for legumes other than white clover and the impact of legume-based systems on the environment compared with other systems should be monitored by a set of reliable indicators

Conclusions and prospects

- For livestock producers choosing legume/grass swards: trade-offs between performance per head and performance per hectare
- Fundamental modification of forage-based systems (Rochon *et al.*, 2004):
  - greater extensification
  - extension of the grazing season
  - reduction in the conservation of fodder resources
  - decrease of concentrate use per litre of milk
  - introduction of new management practices
- In dairy production, the quest for increasingly high production per cow would not be compatible with these new goals

Conclusions and prospects

- Sufficient income by decreasing production costs through reducing:
  - manpower, mainly by extending the grazing season
  - inorganic N fertilizer use on grasslands and in grassland/crop rotations
  - the housing period and the proportion of conserved feeding in the total diet
  - concentrate per kg output thanks to a better intake of legumes compared with grasses

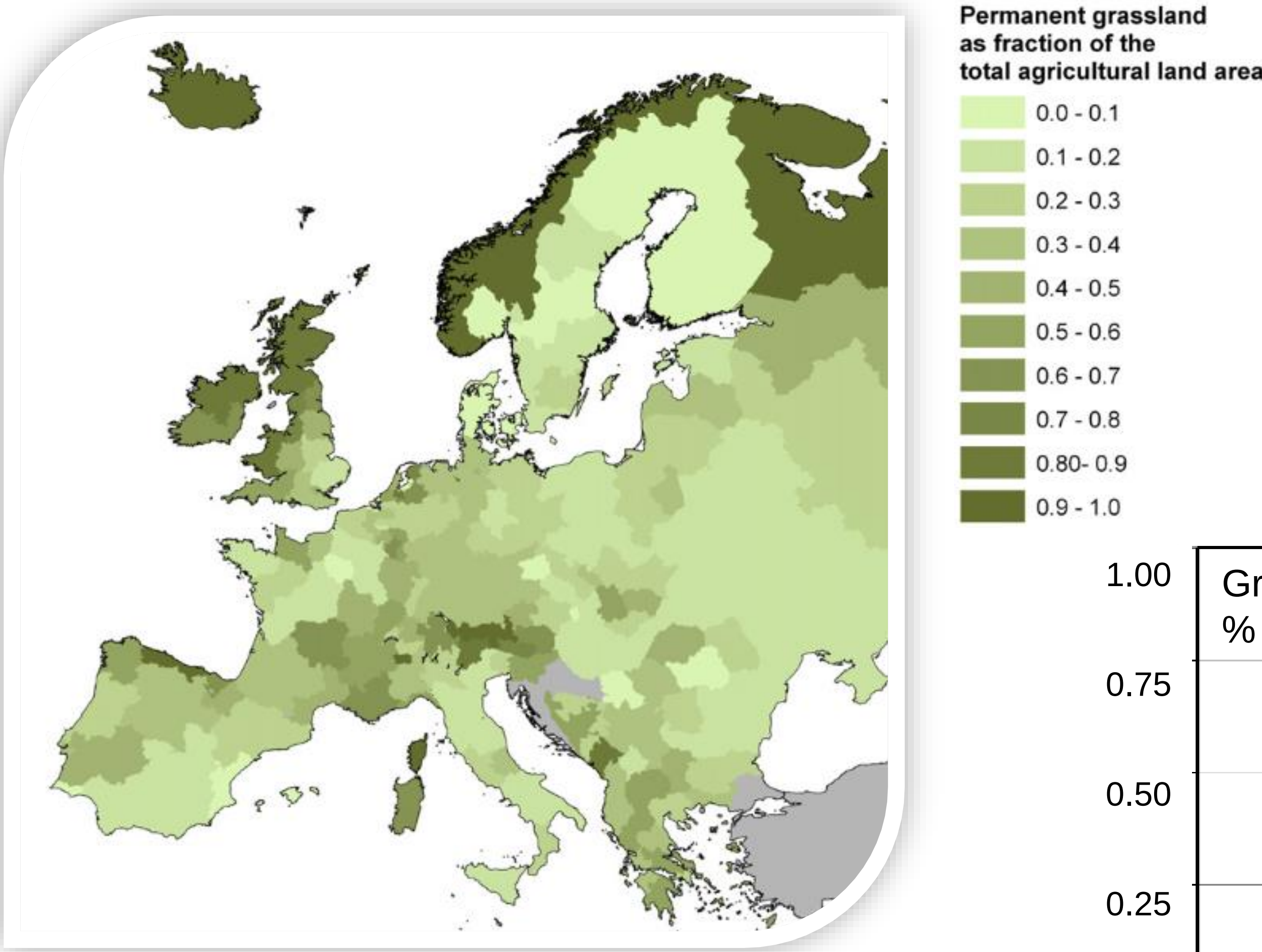
- and through improving:
  - conservation of legumes
  - persistence (disease resistance, competitiveness)
  - overall herbage quality for increased intake

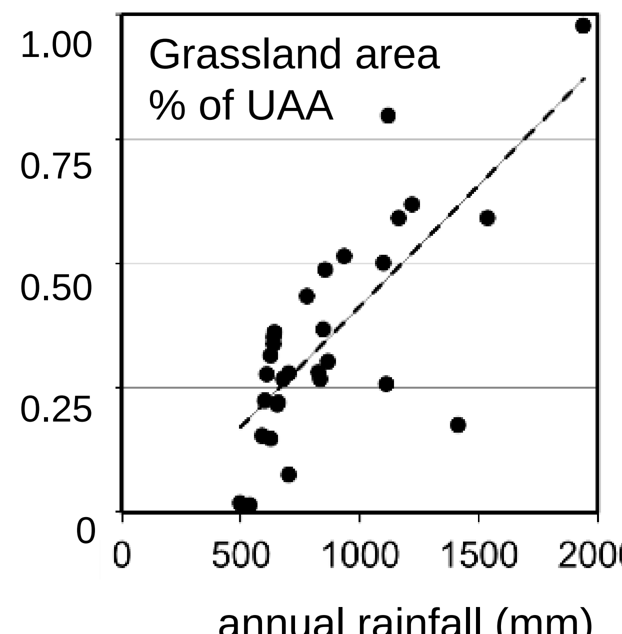
Germany

Inno4Grass

Grassland syllabus Germany

Permanent grassland area in Europe





(Smit et al. 2008, AgricSyst 98, 208-219, Eurostat 2014)

Grasslands and management systems are highly variable

(Source: Isselstein, 2018)

Grassland Ecosystem Services – ‘The big five’:

1. Production
2. Biodiversity
3. Climate
4. Water
5. Culture

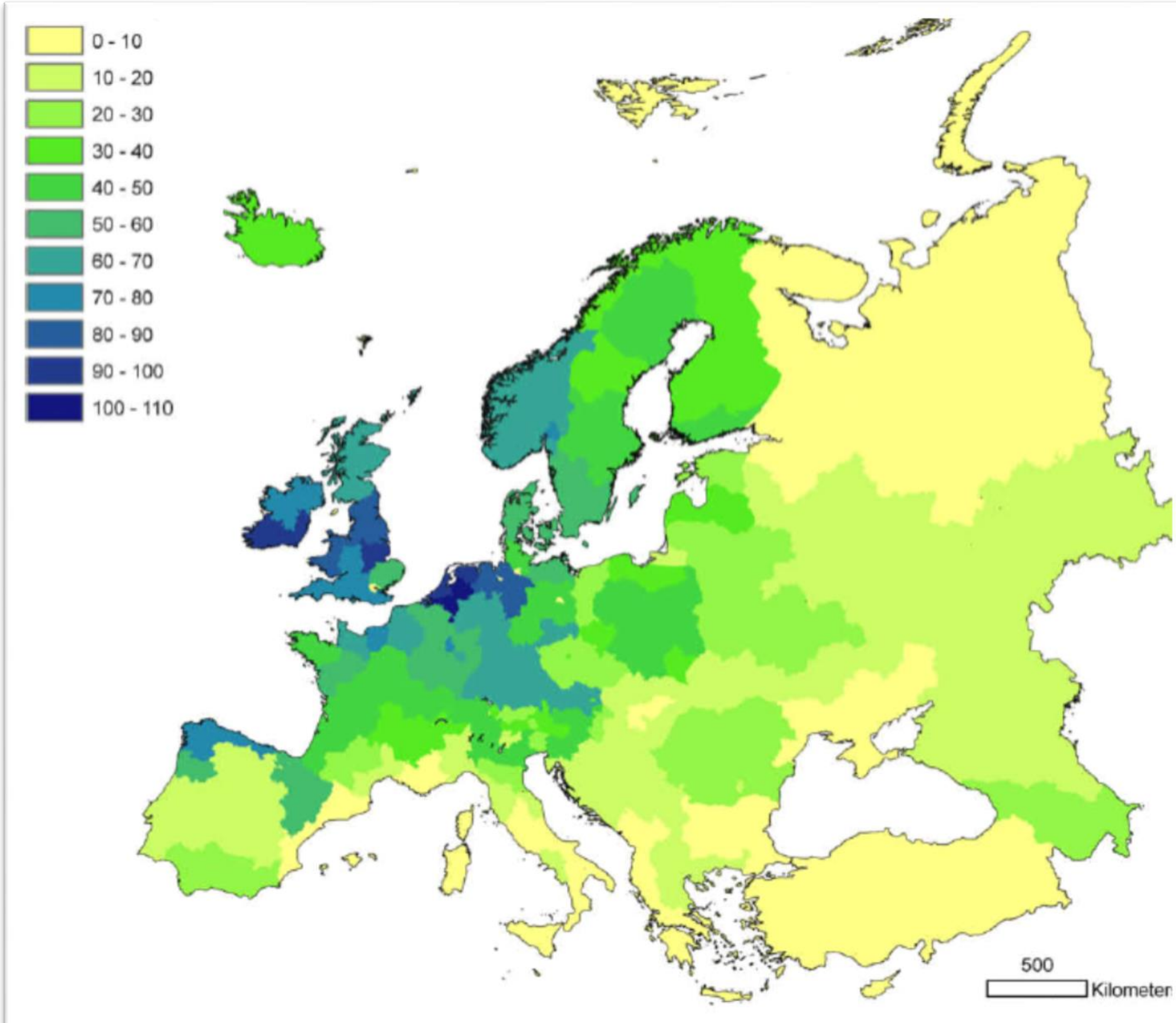
(Source: Isselstein, 2018)

Grassland Ecosystem Services – 'The big five':

1. **Production**
2. Biodiversity
3. Climate
4. Culture
5. Water

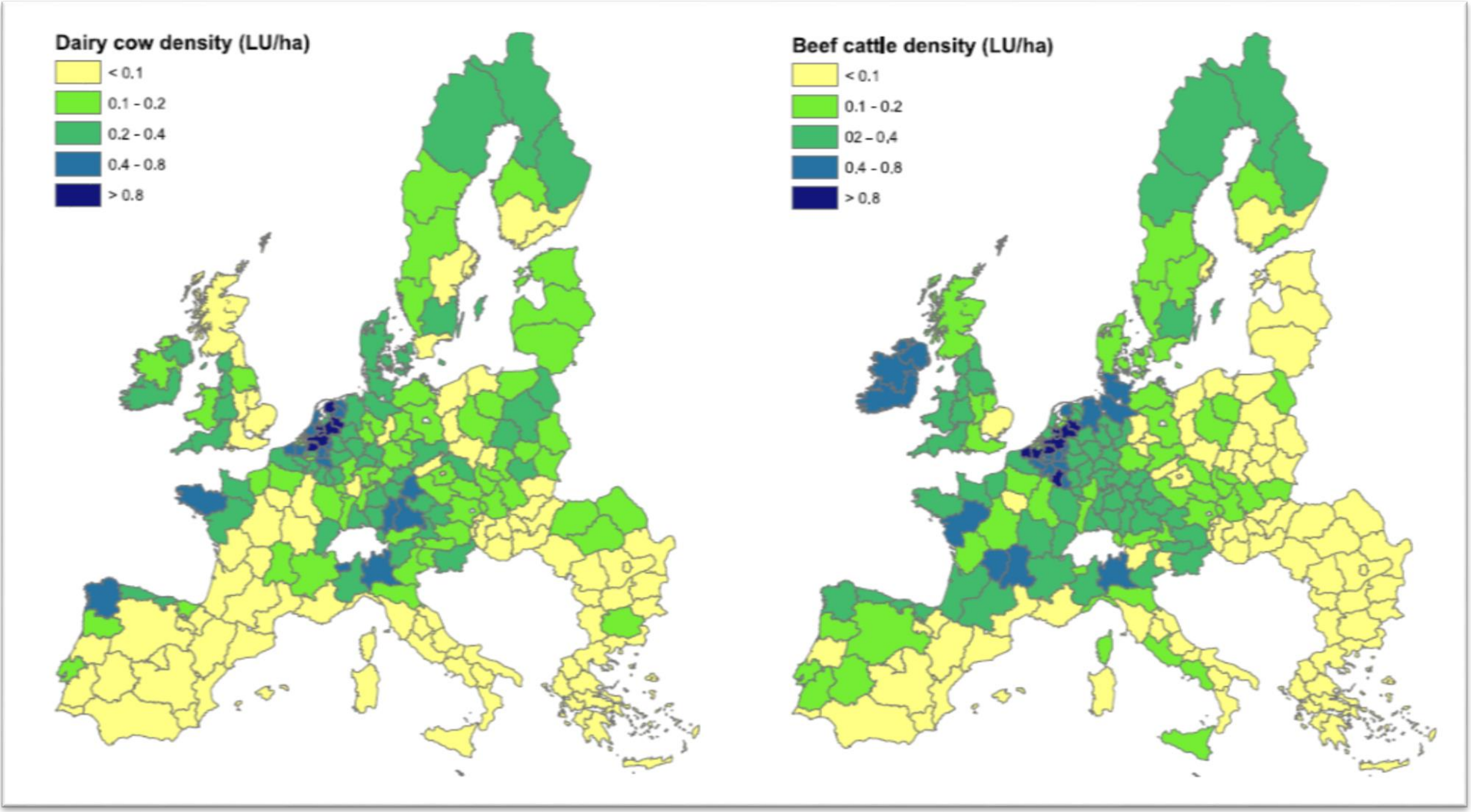
(Source: Isselstein, 2018)

Estimated grassland productivity in decitons per hectare
(Smit et al. 2008, AgricSyst 98, 208-219, Eurostat 2014)

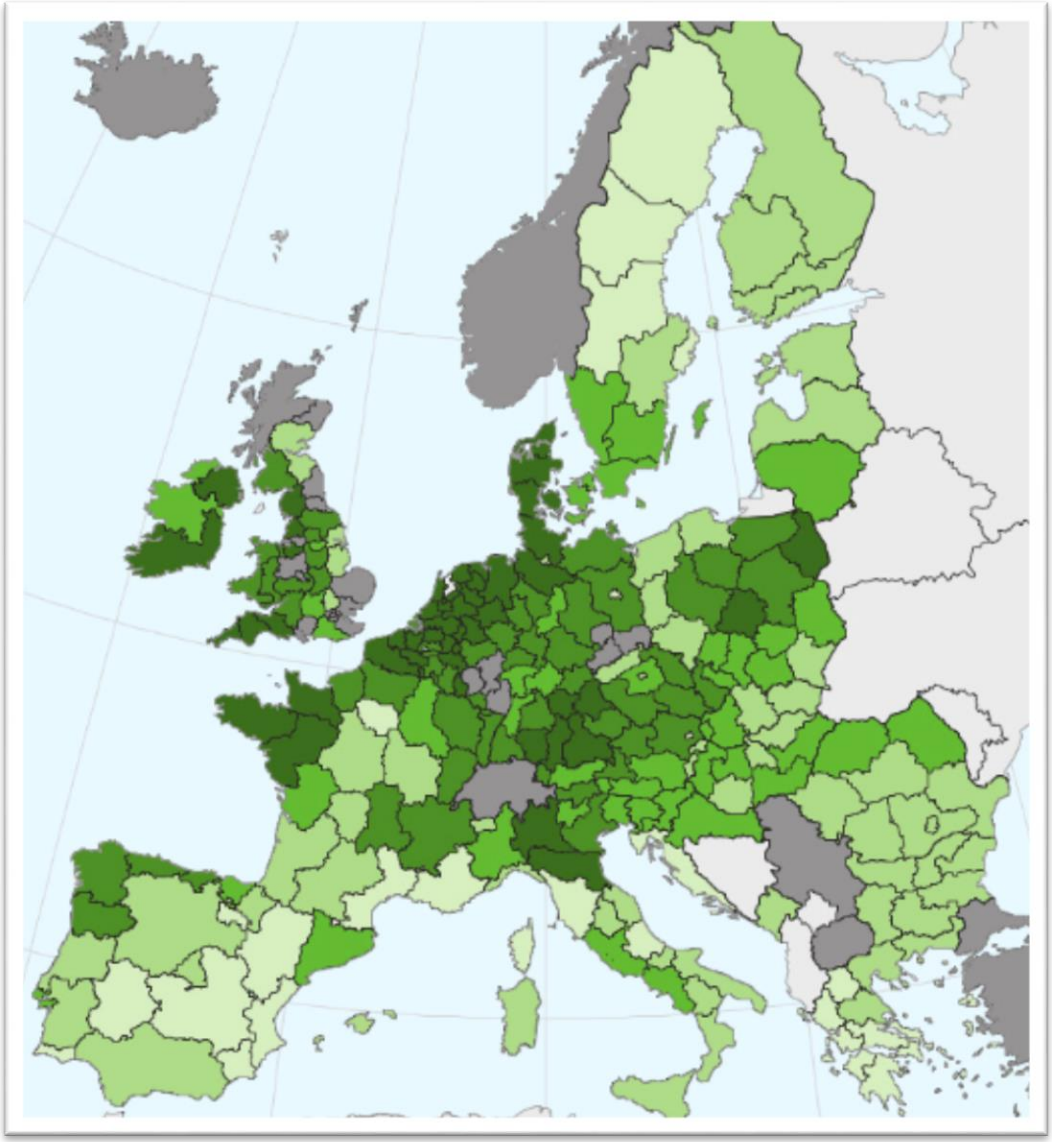


Dairy cow and beef cattle density in 2004 for EU-27 states

(Lesschen et al., 2011)



Milk production in Europe by region, 2012
(eurostat 2014)



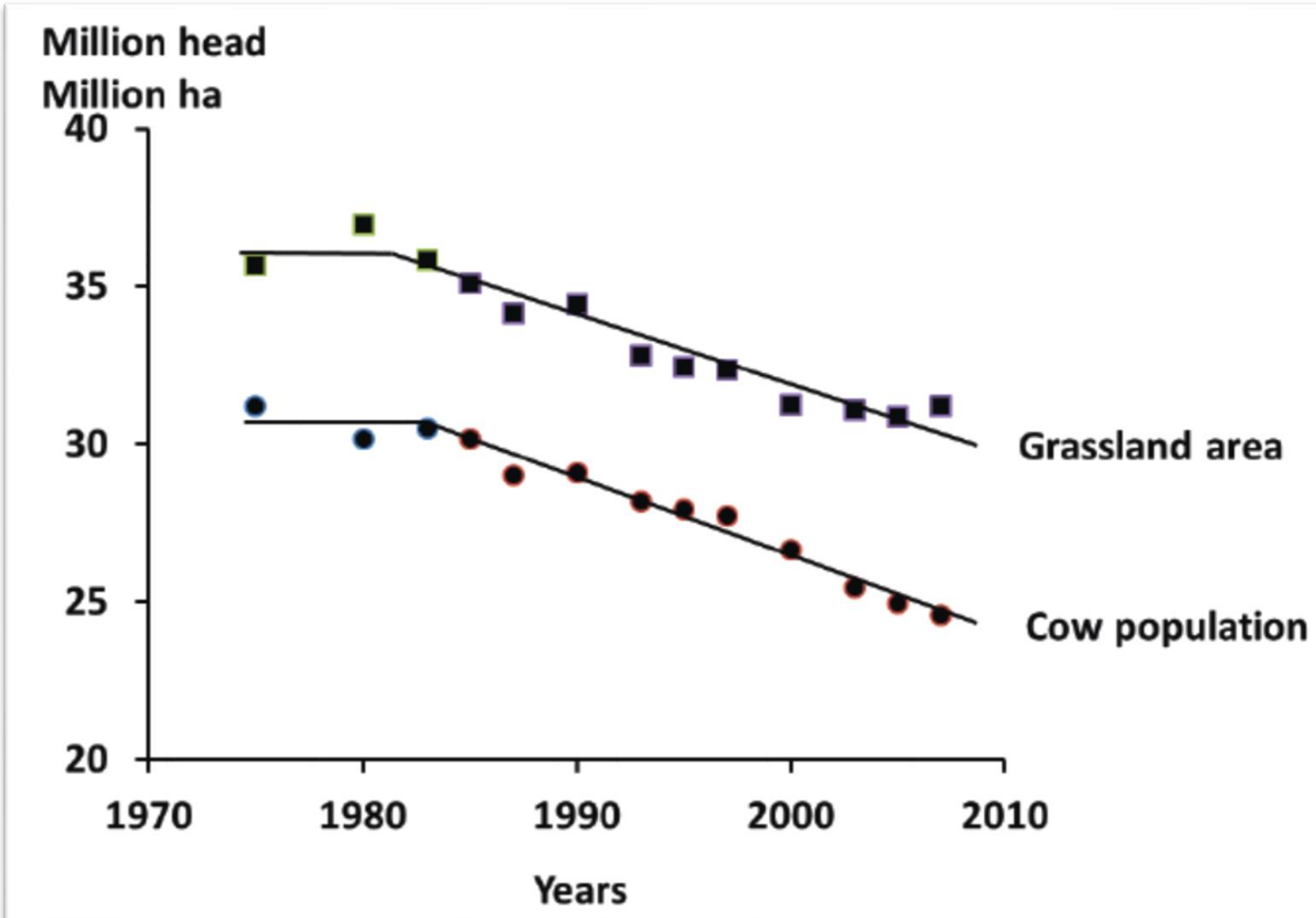
(tonnes per km²)

EU-28 = 34.0

- < 5.0
- 5.0 – < 20.0
- 20.0 – < 35.0
- 35.0 – < 100.0
- >= 100.0
- Data not available

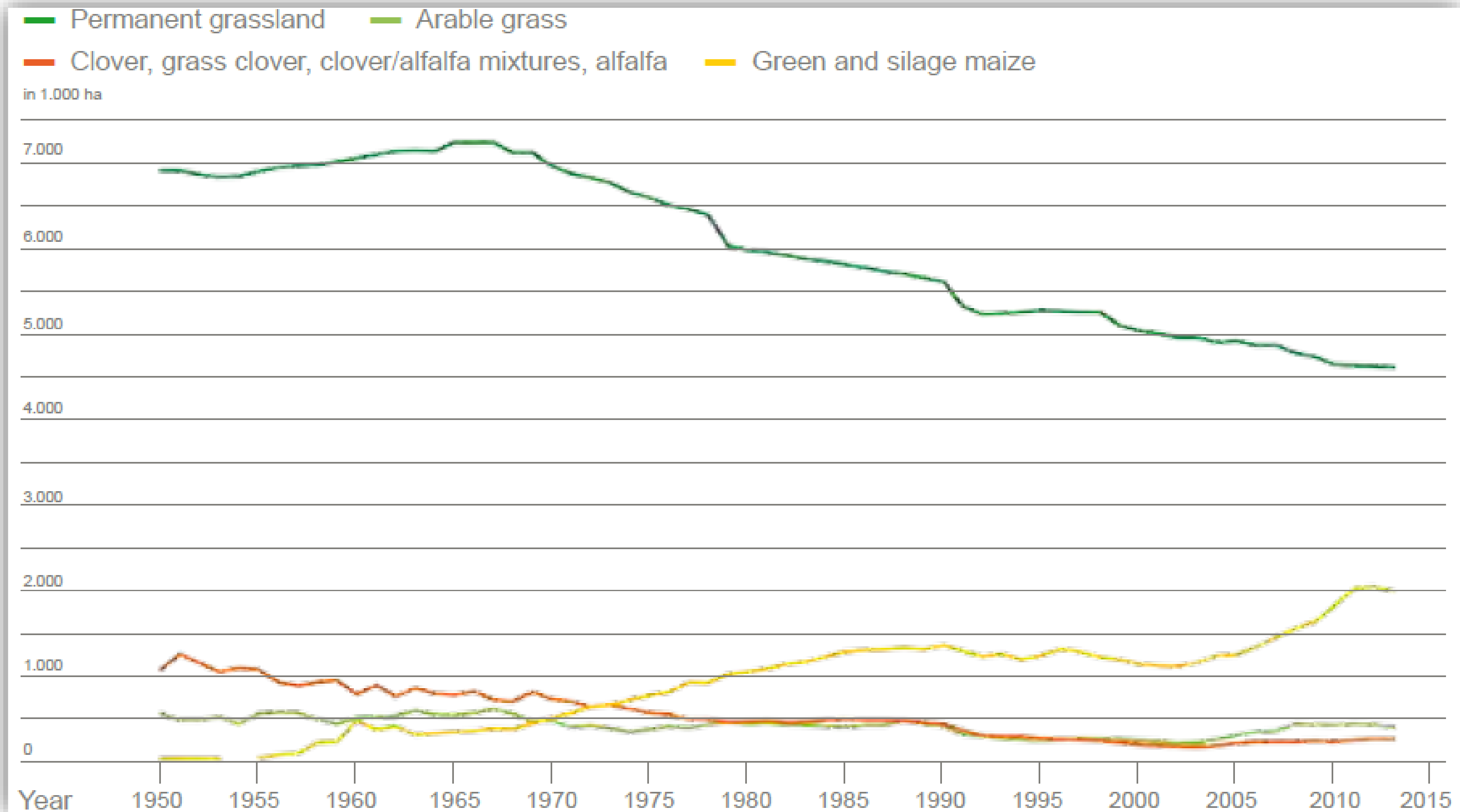
Development of permanent grassland area and cow number in EU-9 countries

(Eurostat 2010, Peyraud & Peeters, 2016)



Development of the forage production area in Germany

(DAFA 2015: The DAFA research strategy)



Feedbasis for dairy production (energy, NEL) in Germany in relation to estimation procedures

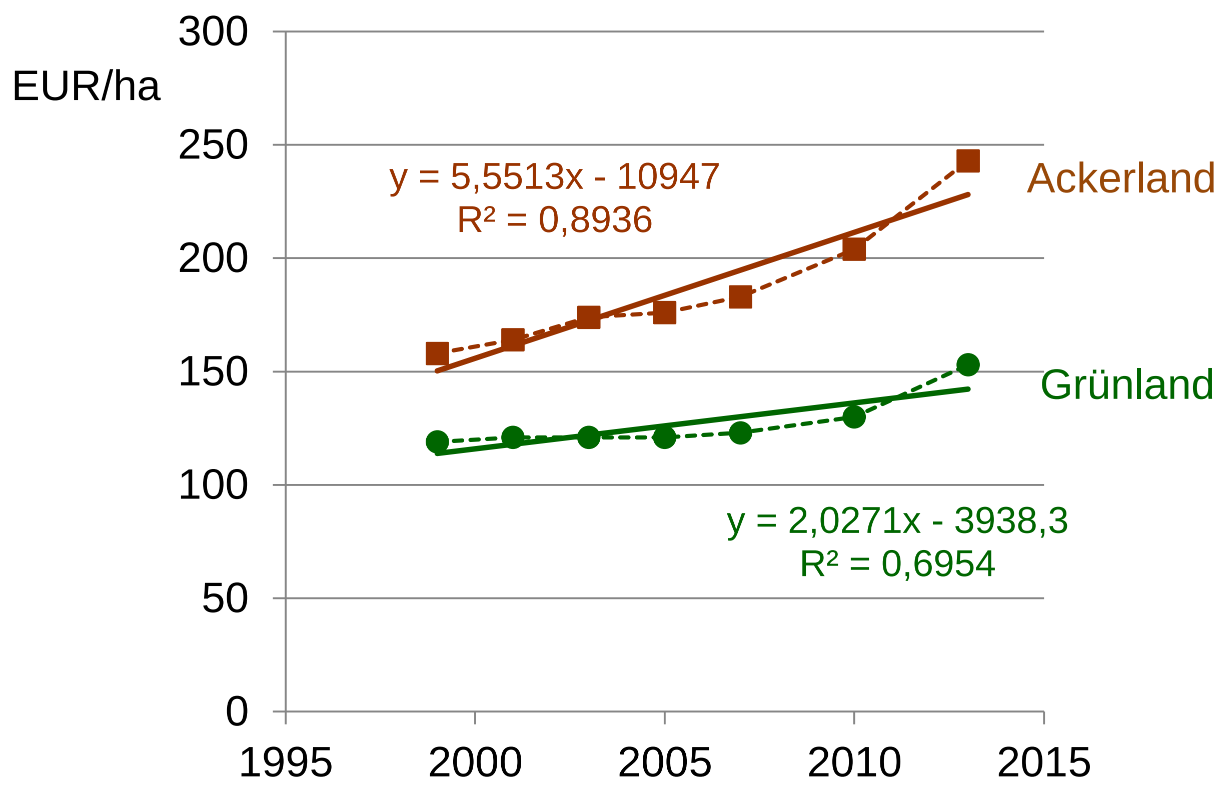
	estimation	
feedstuff	potentially	residual
grass	43 %	30 %
maize	28 %	34 %
concentrates	29 %	36 %

Ortgies 2017, unpubl.

estimation procedure

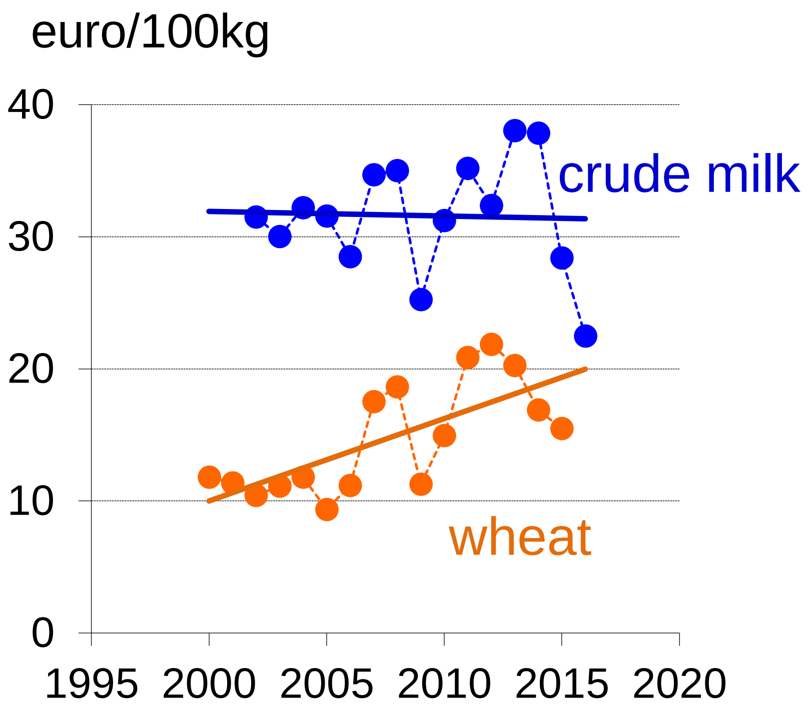
- potentially: grassland performance calculated from official yield data
- residual: grassland performance from residual calculation

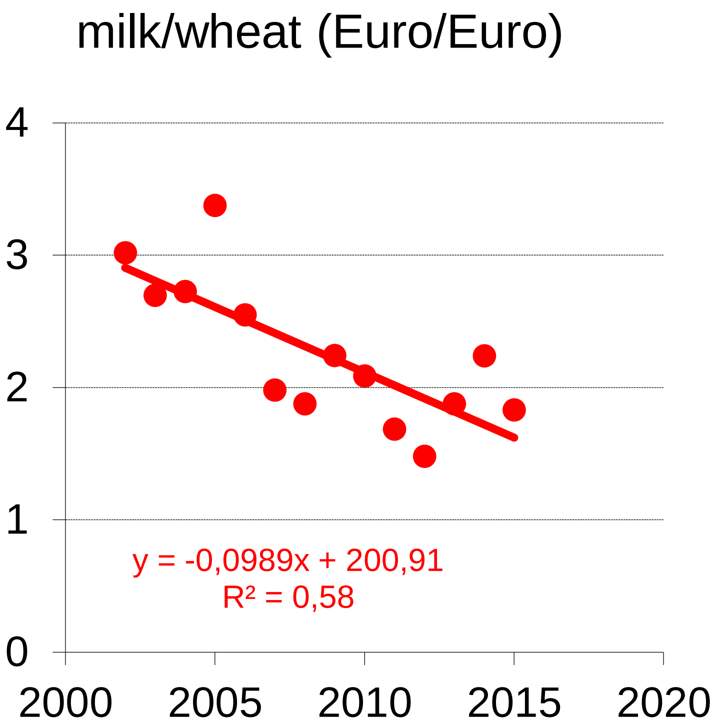
Development of rent prices for arable and grassland in Germany (destatis 2016)



Price development of crude milk and wheat in Germany and relationship of milk revenue to wheat price

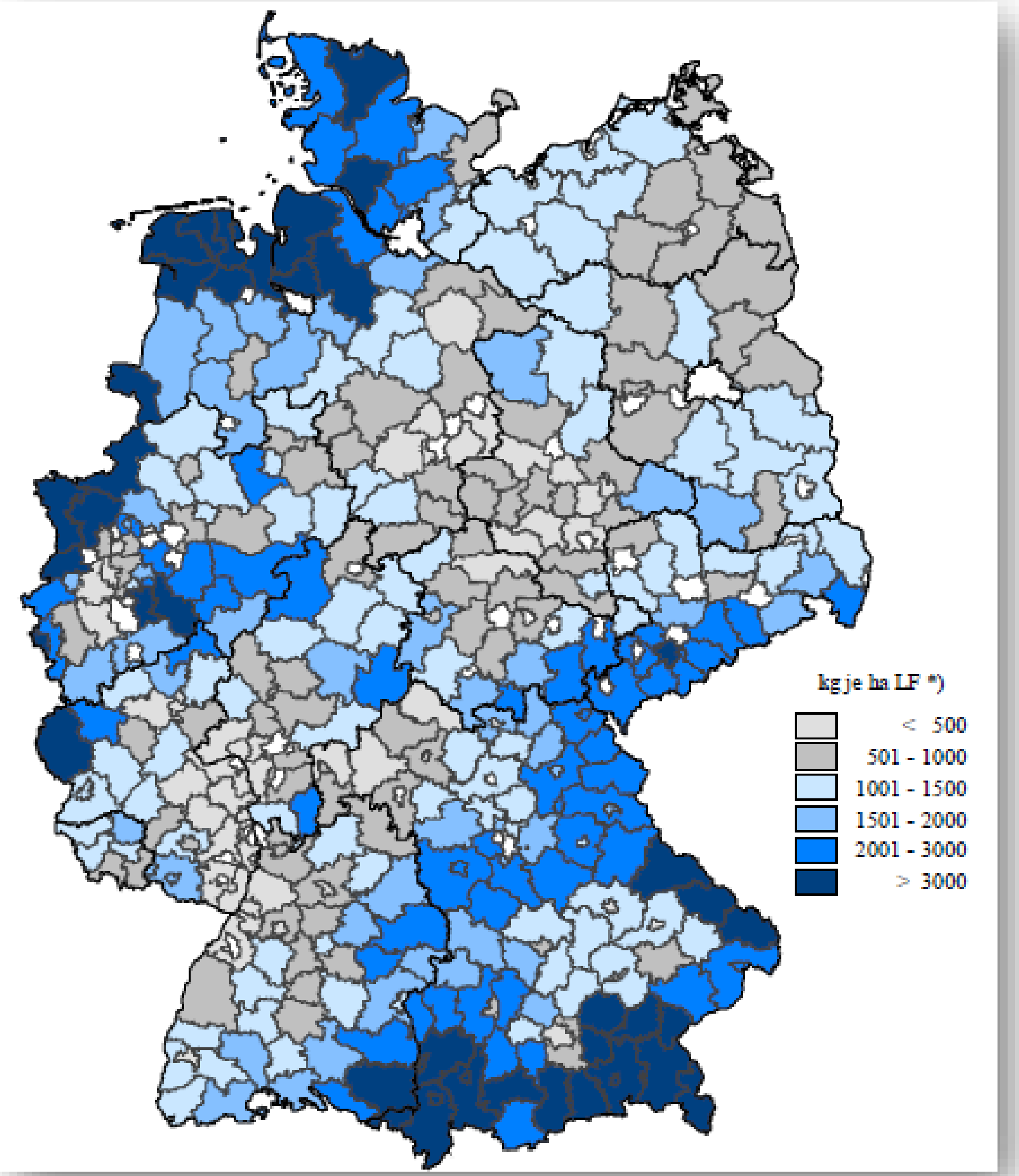
(eurostat 2016)



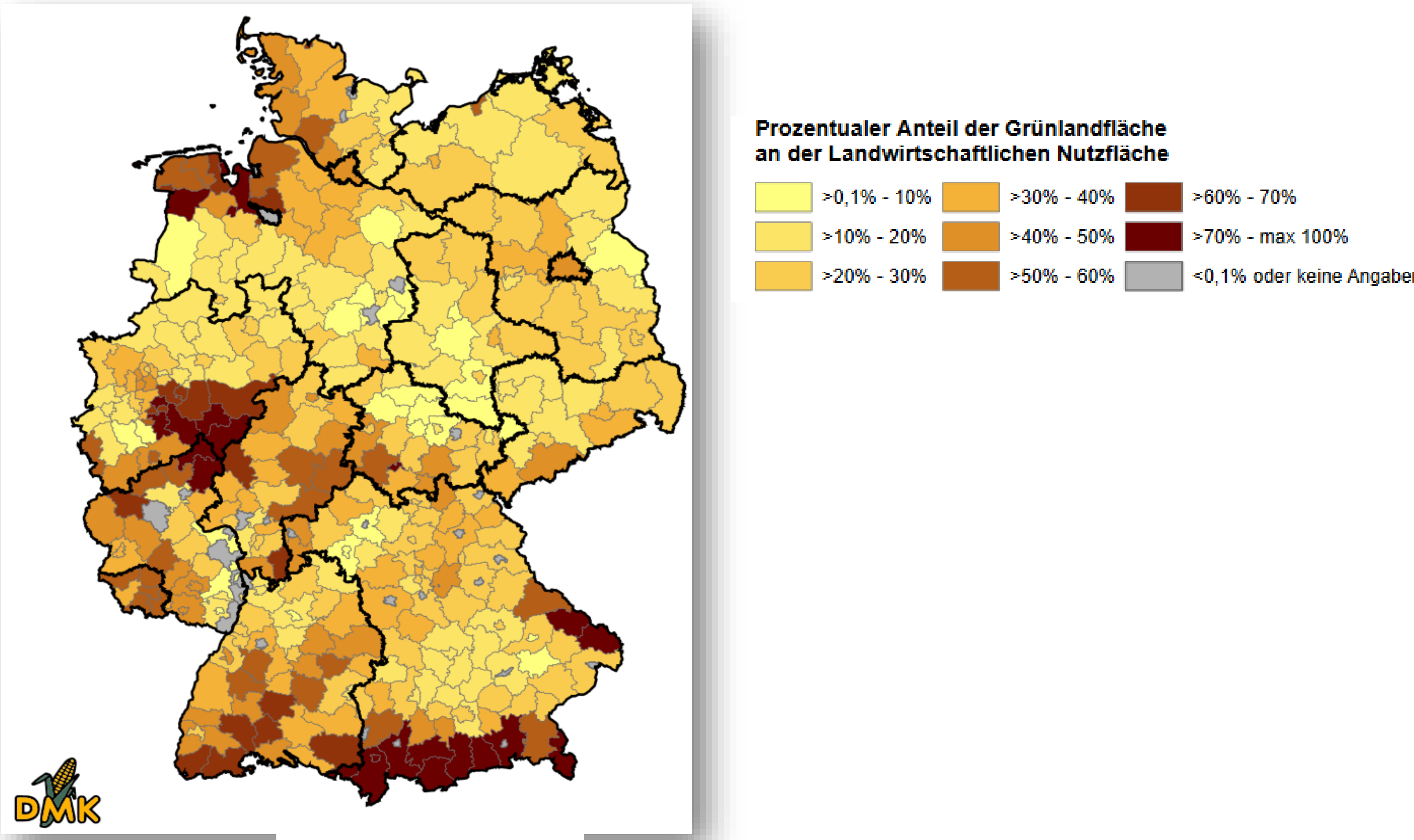


Milk production per ha agriculturally utilized area in Germany

(Lassen et al. 2008)



Permanent grassland area in Germany, data from 2016
(DMK, 2018)



Production trends in grassland in Germany

- Dairy less dependent on grasslands (even though grasslands are often highly productive)

- Marginal grasslands increasingly abandoned from agricultural use

Grassland Ecosystem Services – ‘The big five’:

1. Production
2. **Biodiversity**
3. Climate
4. Culture
5. Water

(Source: Isselstein, 2018)

High nature value farmland in Germany

- Grassland is an important contributor to the biodiversity in the rural landscape
- e.g. German wide study on ‚high nature value (HNV)-farmland*)‘ (Matzdorf et al. 2010, Fuchs 2011)

‚HNV-farmland‘: 13 % of the total farmed area

from this

‚HNV-grassland‘: 5,5 % (→ 14 % of total grassland)

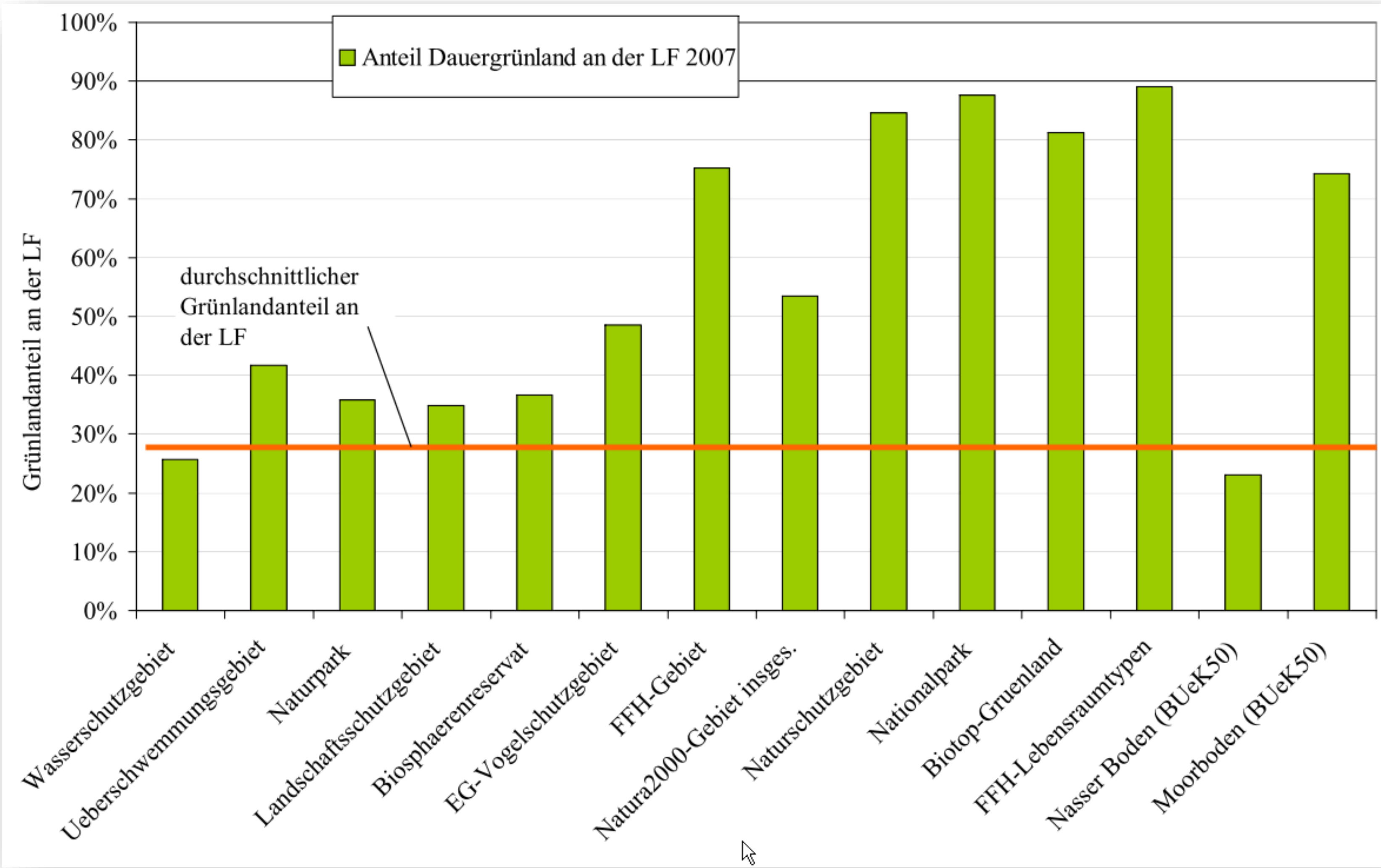
‚HNV-arable land‘: 1,5 %

‚HNV-elements‘: 4,6 %

***) productive and non productive agriculturally utilized area**

Grassland area (%) in designated nature conservation and environmentally sensitive areas in Germany

(Osterburg et al. 2009)



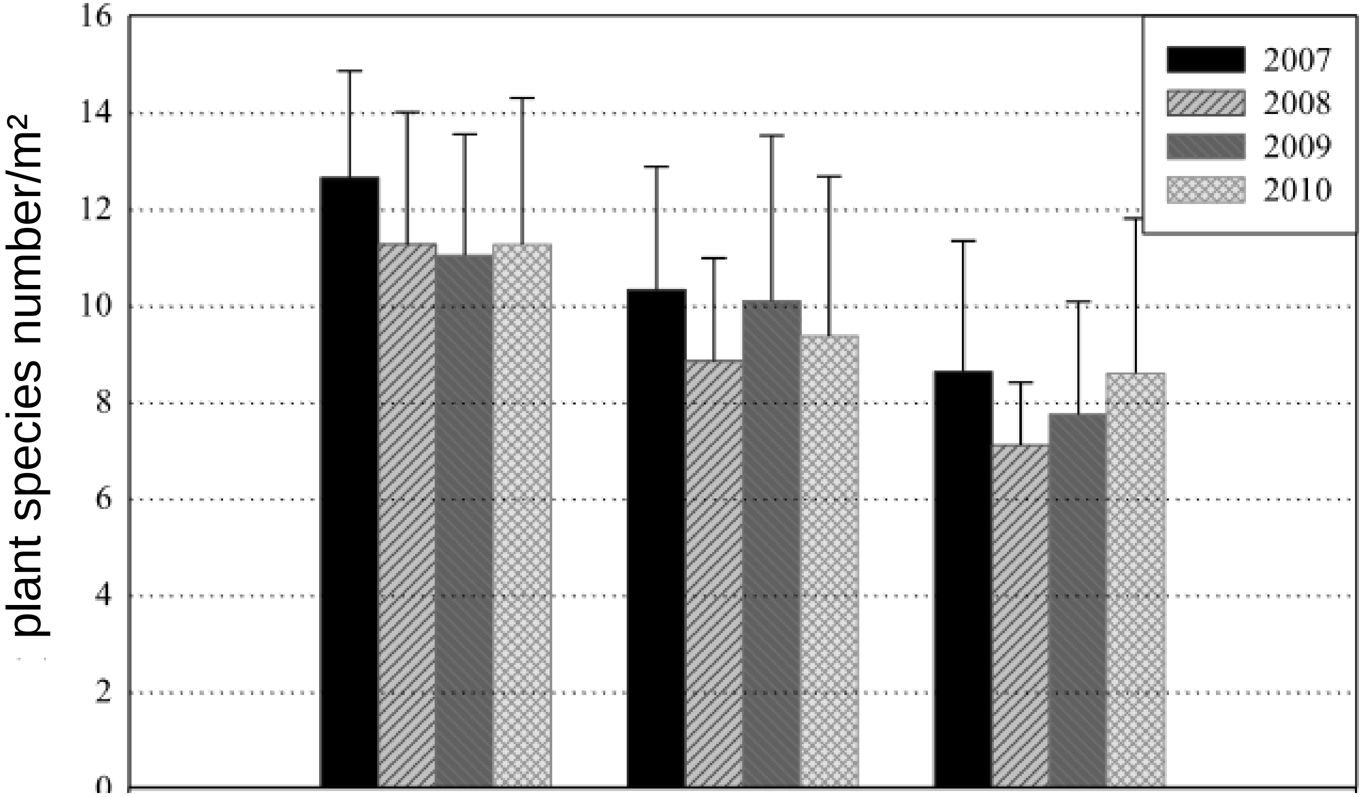
Status of FFH habitats in grasslands

Zustand der Grünland-Lebensräume (FFH-Bericht 2013)	Nordwestdeutsches Tiefland		Ost- und Süddeutschland		Alpen	
	Erhaltungs-zustand	Trend	Erhaltungs-zustand	Trend	Erhaltungs-zustand	Trend
Basenreiche oder Kalk-Pionierrasen	schlecht	-	unzureichend	-	keine Vorkommen	
Subkontinentale basenreiche Sandrasen	schlecht	-	unzureichend	=	keine Vorkommen	
Schwermetallrasen	unzureichend	?	unzureichend	-	keine Vorkommen	
Boreo-alpines Grasland auf Silikatböden	keine Vorkommen		unzureichend	=	unzureichend	=
Alpine und subalpine Kalkrasen	keine Vorkommen		keine Vorkommen		unzureichend	=
Kalk-(Halb-)Trockenrasen und ihre Verbuschungsstadien (z.T. orchideenreiche Bestände)	unzureichend	?	unzureichend	-	unzureichend	-
Artenreiche Borstgrasrasen	schlecht	-	unzureichend	-	unzureichend	-
Steppenrasen	unzureichend	-	unzureichend	-	keine Vorkommen	
Pfeifengraswiesen	schlecht	-	schlecht	-	günstig	=
Feuchte Hochstaudenfluren	schlecht	-	unbekannt	?	günstig	=
Brenndolden-Auenwiesen	schlecht	?	schlecht	=	keine Vorkommen	
Magere Flachland-Mähwiesen	schlecht	-	schlecht	-	schlecht	-
Berg-Mähwiesen	keine Vorkommen		schlecht	-	unzureichend	-

trends: = stable, + getting better, - getting worse, ? unknown

(BFN, 2014)

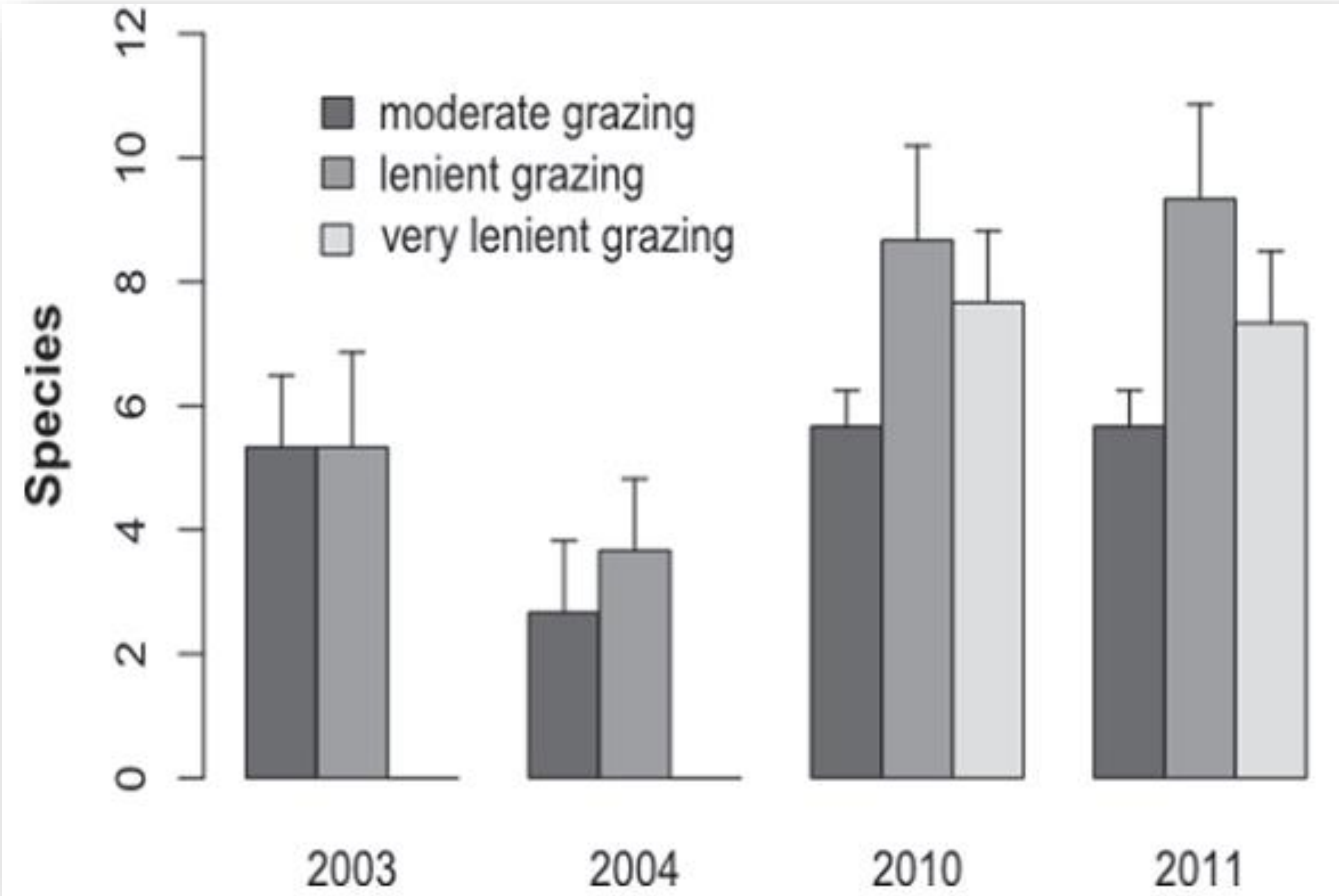
Plant species number of patches of different sward height in a long-term grazing experiment



0 – 6 6 – 12 > 12 sward height cm

(Wrage et al. 2012, AEE 155, 111-116)

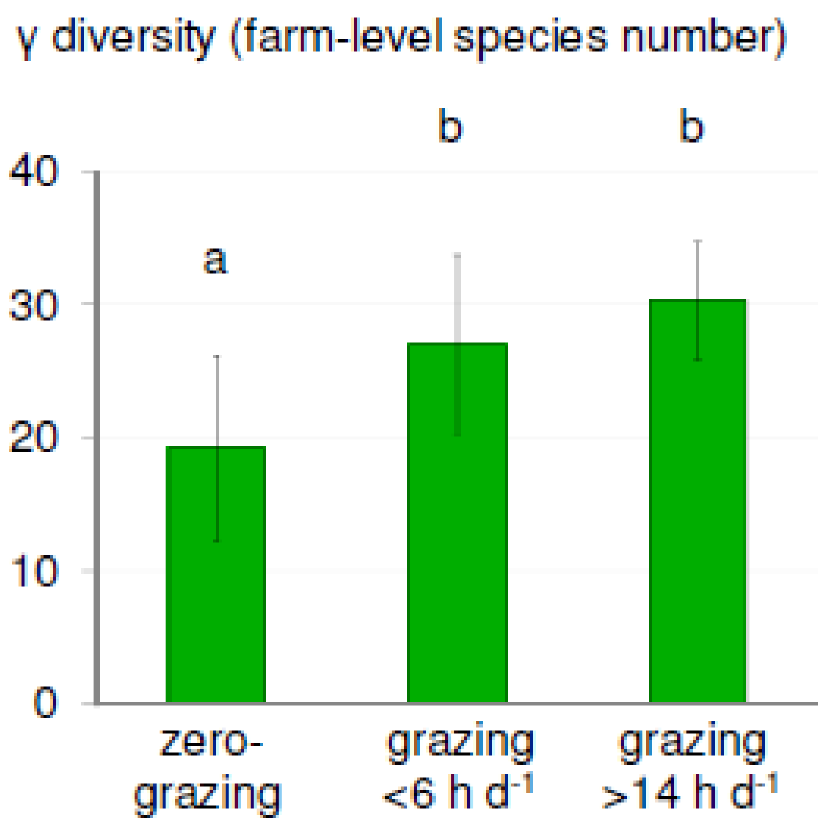
Butterfly species richness in relation to the grazing intensity in a long-term grazing experiment

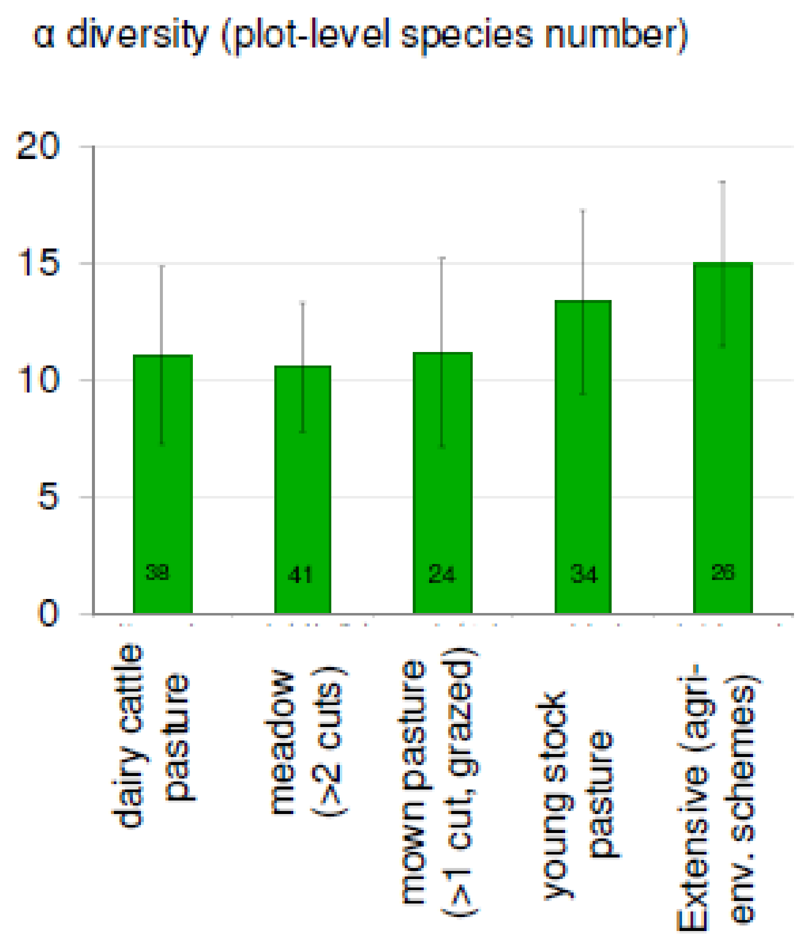


(Jerrentrup et al. 2014,
JApplEcol 51, 968-977

Farm (left figure) and plot level (right figure) plant species diversity of grasslands of dairy farms in Lower Saxony, depending on grassland utilization

(Breitsameter & Isselstein 2015, GraslSciEur 20, 172-174)





Grassland Ecosystem Services – ‘The big five’:

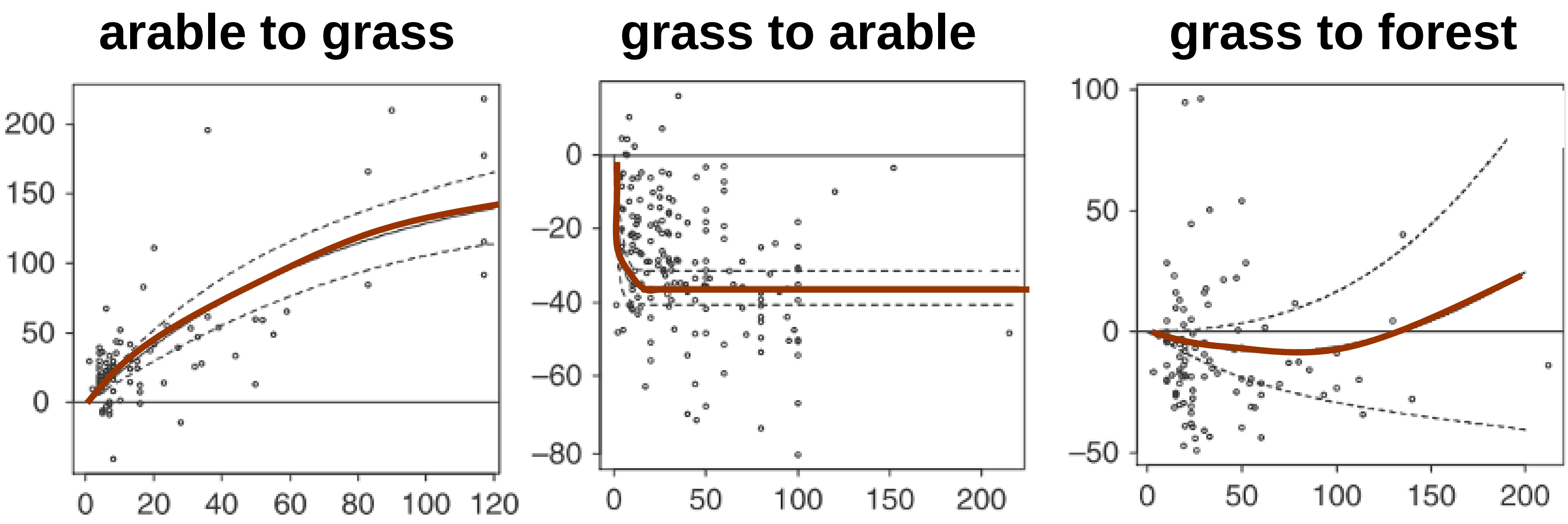
1. Production
2. Biodiversity
3. **Climate**
4. Culture
5. Water

- N20 and CH4 emissions
- Carbon sequestration

(Source: Isselstein, 2018)

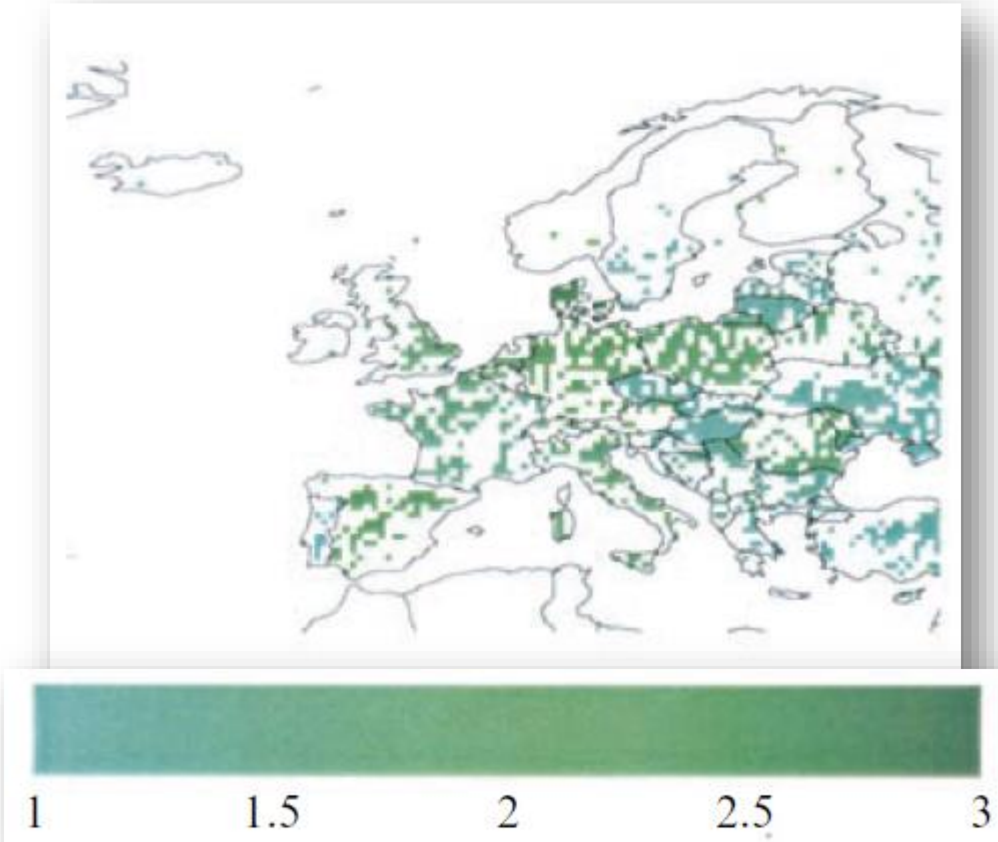
Relative changes (%) in soil organic carbon after land-use change

(Poeplau et al. 2011, GCB 17, 2415-2427)



years after land use change

Carbon sequestration



t C ha^{-1}

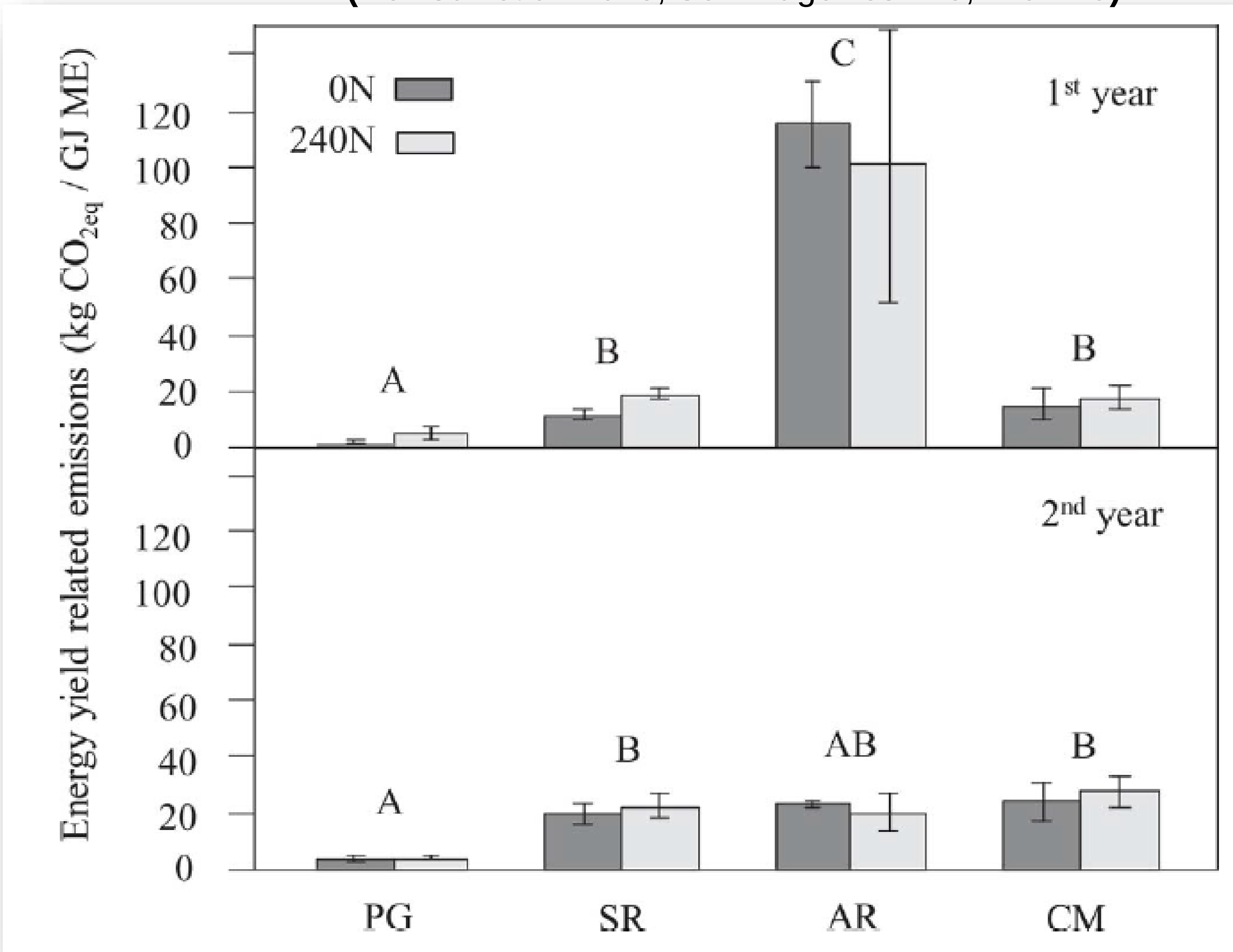
Simulation study on the average annual net effect (t C ha^{-1}) on the carbon content of the soil organic matter due to conversion of arable land into grassland

(Vleeshouwers and Verhagen, 2002)

Grassland renovation/conversion and yield related emissions

($CO_{2äq}$ ha^{-1}/annual energy yield)

(Reinsch et al. 2018, SoilTillageRes 175, 119-129)



- two experimental years
- shown are results for the first year after renovation/conversion of grassland

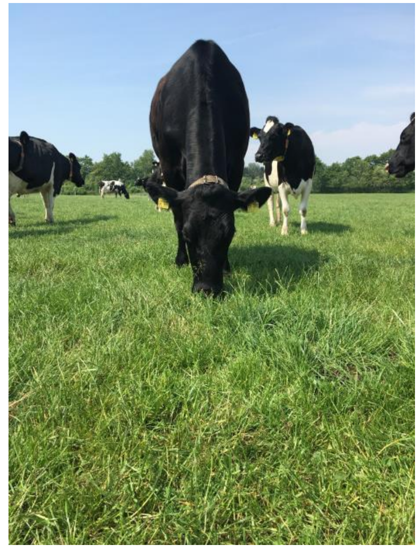
PG: permanent grassland undisturbed
SR: spring renovated grassland
AR: autumn renovated grassland
CM: grassland conversion to silage maize

Grassland Ecosystem Services – ‘The big five’:

1. Production
2. Biodiversity
3. Climate
4. **Culture**
5. Water

- Aesthetic value of grasslands
- Recreation
- Nature education

(Source: Isselstein, 2018)



Aesthetic value of grasslands

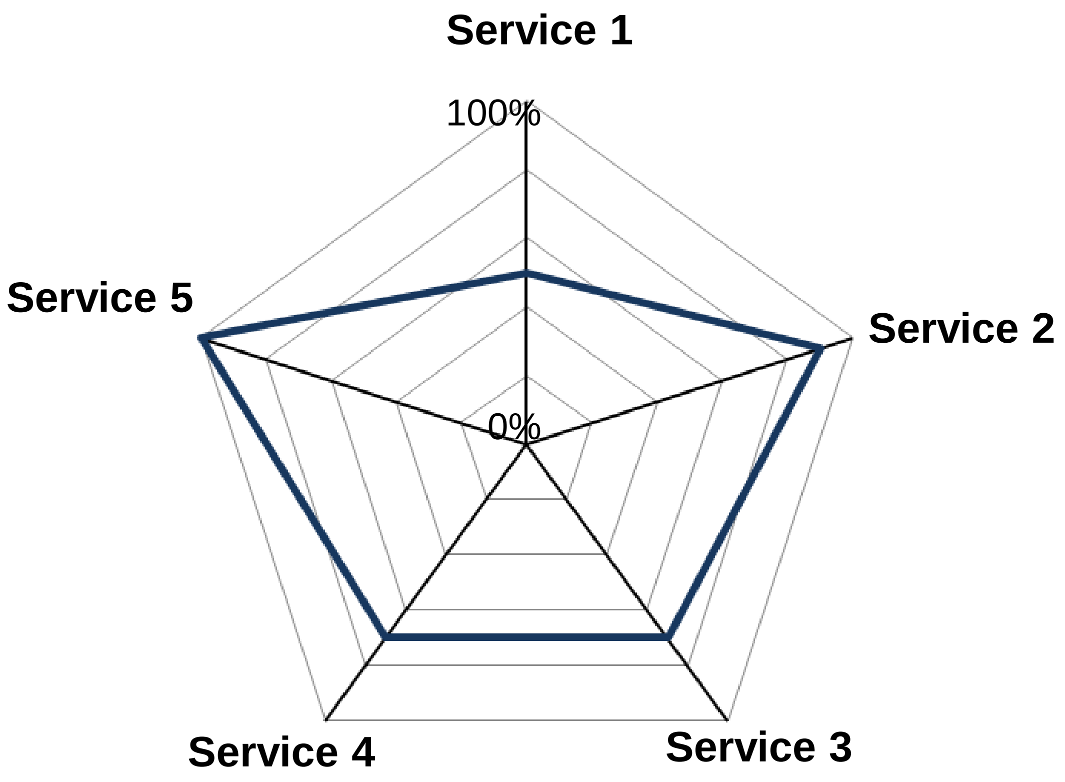
Nature education

Recreation

Managing Trade-offs among functions …..

1. Knowing the (causal) relationship among different services
2. Identifying the effect of management measures on the delivery of multiple services

Relative amount of ecosystem services delivered by grasslands (schematic)

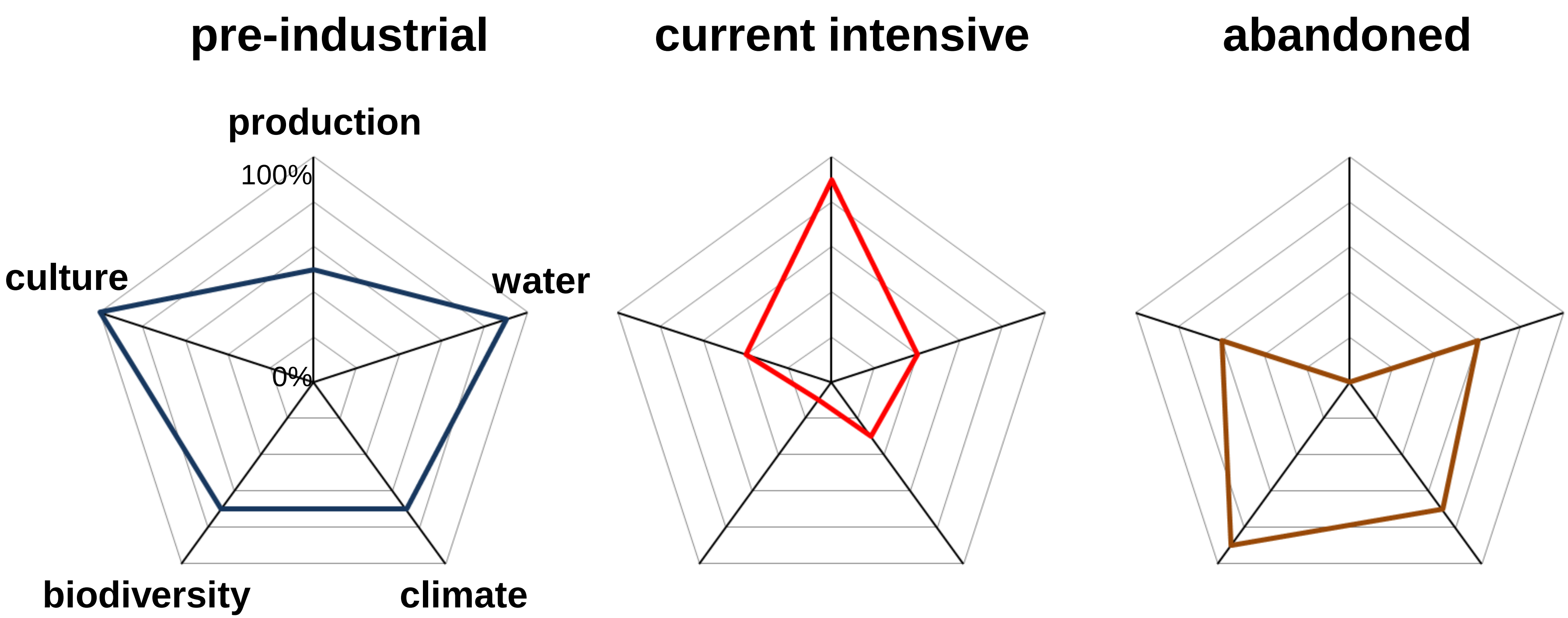


Ecosystem services vary from 0 (no service/disservice) to 100% (maximum service possible under the particular conditions)

(Source: Isselstein, 2018)

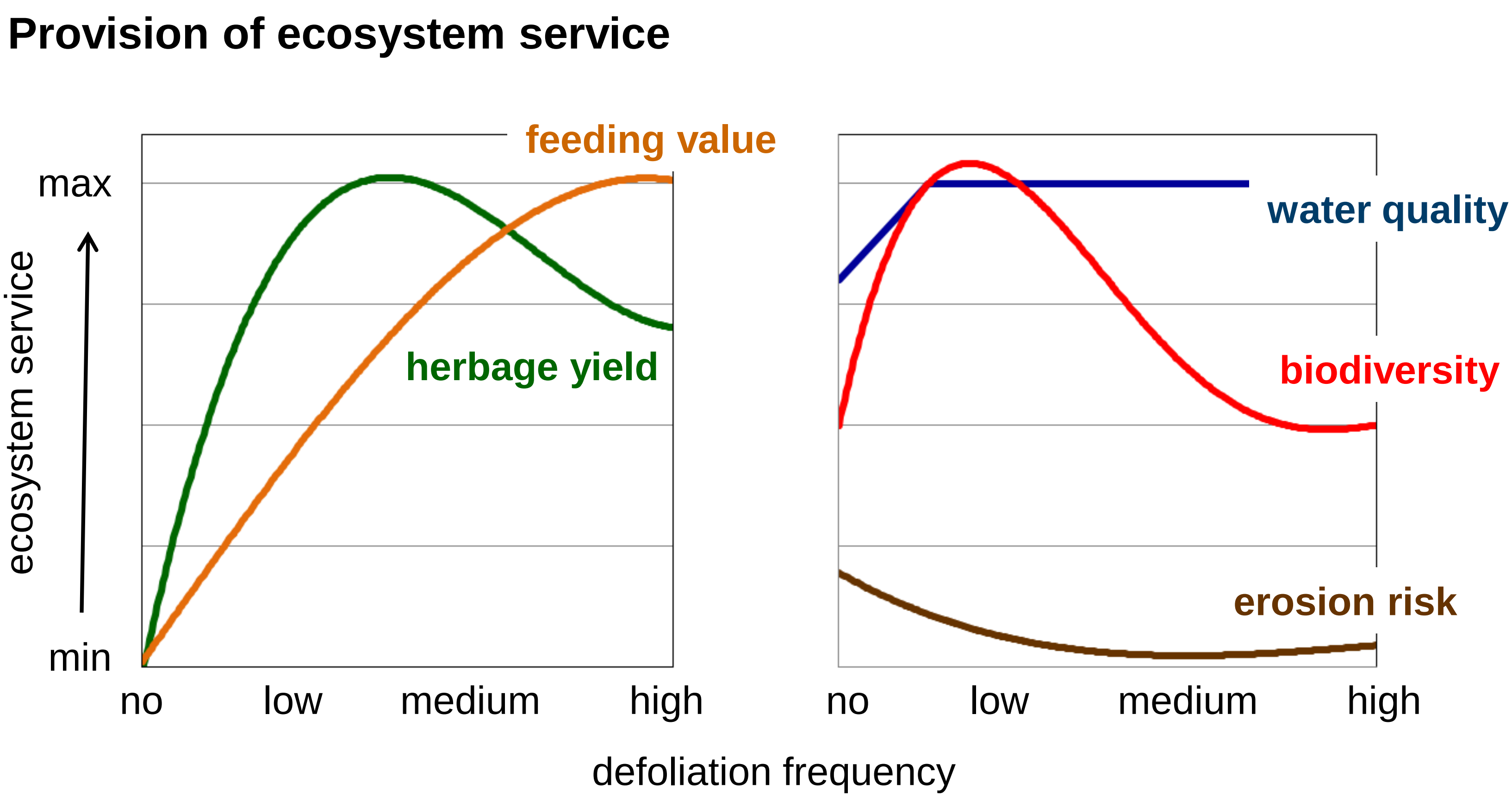
Ecosystem services delivered by grasslands (schematic)

ecosystem services vary from 0 (no service/disservice) to 100% (maximum service possible under the particular conditions)



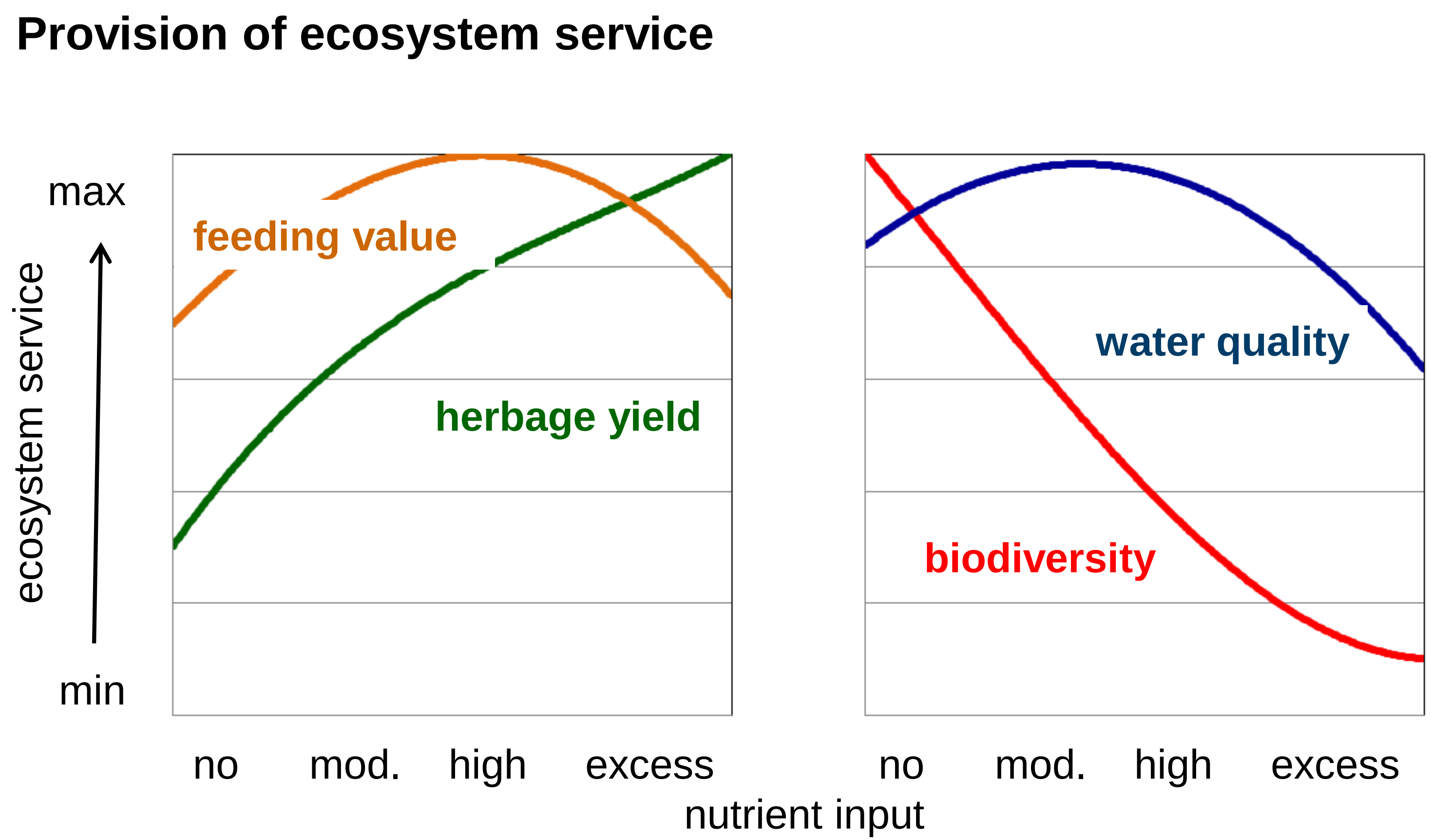
(Isselstein & Kayser 2014: Grassl.Sci.Eur. 19, 199-214)

Grassland management intensity and ecosystem services outcomes (schematic)



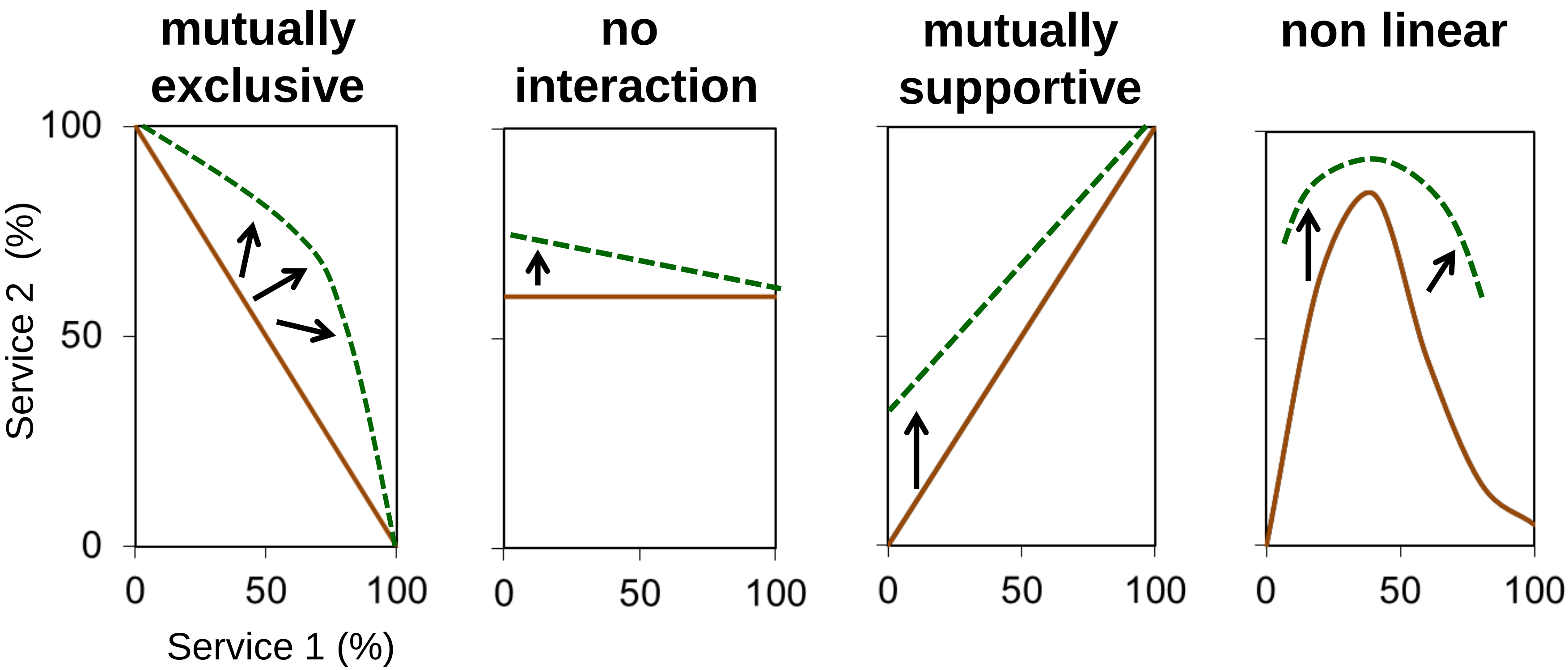
(Source: Isselstein, 2018)

Grassland management intensity and ecosystem services outcomes (schematic)



(Source: Isselstein, 2018)

Schematic representation of the different types of functional relationships between two ecosystem services



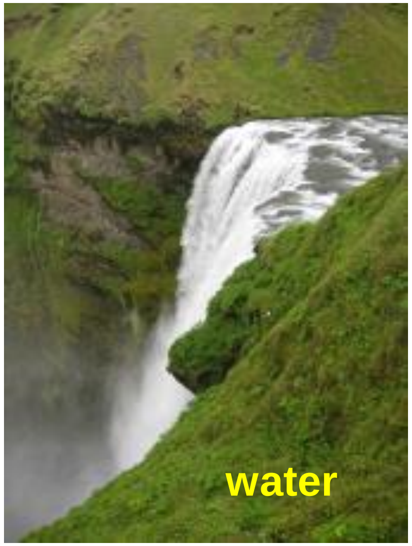
Solid line: current status, dashed line: changed relationship, e.g. through improved management, with increased total service

(Isselstein & Kayser 2014: Grassl.Sci.Eur. 19, 199-214)

Grassland Ecosystem Services – 'The big five':

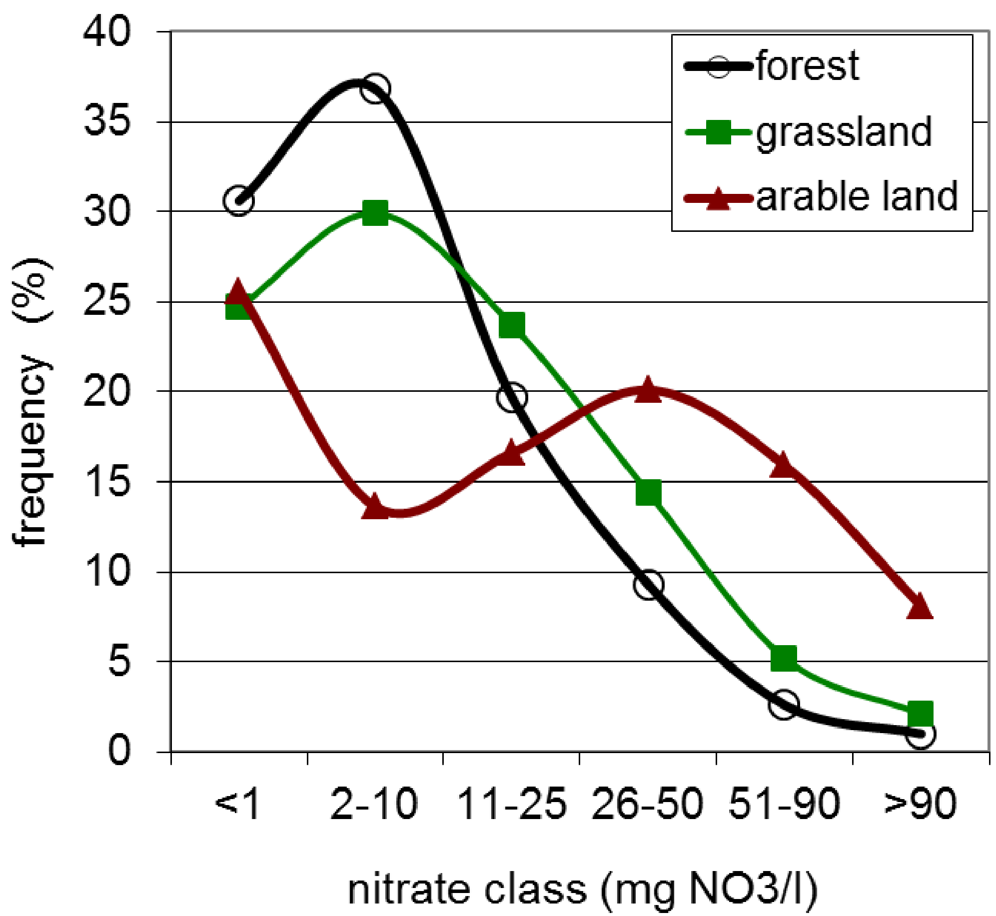
1. Production
2. Biodiversity
3. Climate
4. Culture
5. **Water**

- groundwater recharge
- surface water runoff / flooding and erosion risks
- quality of surface and groundwater

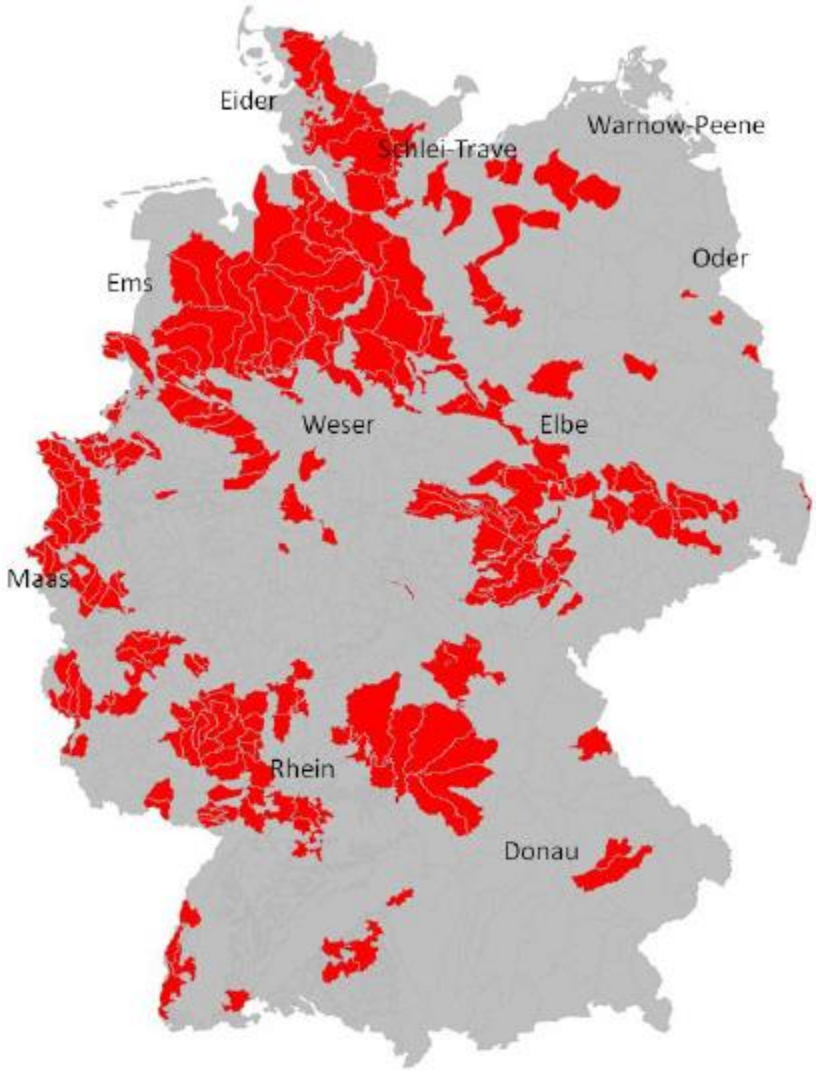


(Source: Isselstein, 2018)

Nitrate concentration in (leaching) soil water under different land use systems (UBA 2010)



Environmental issues – groundwater quality



(SRU, 2015)

Nitrate concentrations in groundwater bodies exceeding the threshold of the water framework directive

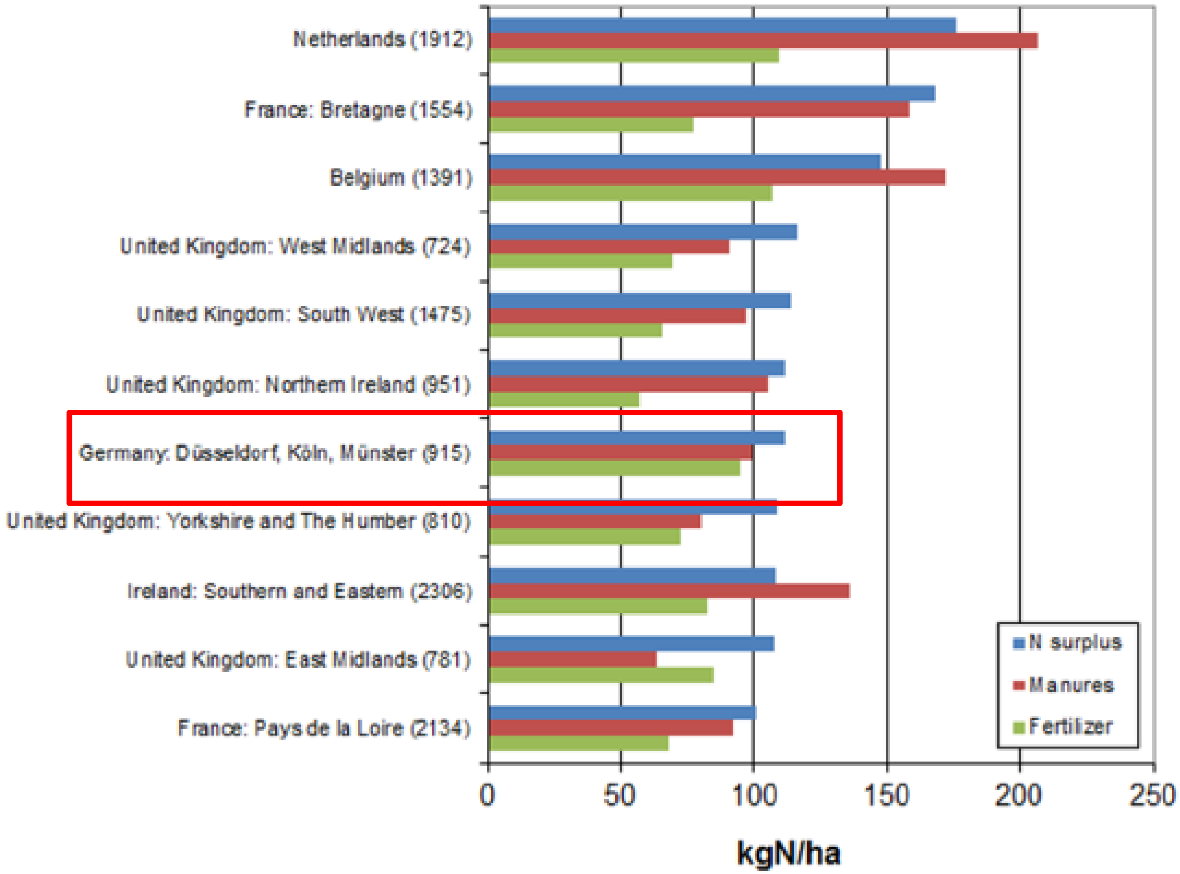
→ Regions with livestock production face problems!

→ Grassland typically no peak emmitant of nitrates to groundwater

→ Not necessarily grassland – but grassland is part of the farms

→ Consequently: on agricultural area higher untilization efficiency of excreted nutrients required, i.E. **N**itrogen

Gross N balances in several european states



(Van Grinsven et al. 2012)

Annual soil N balance (soil N surplus) and N inputs from manure and fertiliser in 2008

→ 70% of n surplus affects environment primarily via nh_3, no_3, n_2o (uba, 2016)

German **Fertilisation Law** and **Fertilisation Ordinance** amended in 2017 to fulfill requirements regulated in the Nitrates Directive (1991)

Fertilization Law (2017) now formulates in **§1 Purpose**

„…*Purpose of the present law is…..*

1. *to save the nutrition of crop plants…*
2. *….*
3. *to prevent and **omit risk for the ecosystem** due fertilisation…*
4. *to guarantee for **sustainable utilisation** of plant nutrients in the agricultural production, and in particular **to prevent nutrient losses to the ecosystem** as far as possible….“*

→ new paradigm in the fertilisation: **harmonises crop and ecosystem level**

German **Fertilisation Law** and **Fertilisation Ordinance** amended in 2017 to fulfill requirements regulated in the Nitrates Directive (1991)

→ new paradigm in the fertilisation practice: **harmonises crop and ecosystem level**

Fertilization Ordinance (2017) now formulates in **§1 Scope**

„(1) The Ordinance regulates

1. *the Goog Agricultural Practice with respect to* ***fertilisation****….*
2. *the* ***reduction of losses*** *to the ecosystem….“*

→ ***Good Agricultural Practice*** *of fertilisation given:*

→ *maximum nutrient utilisation and low losses*

→ *fertilisation only permitted at high crop demand, otherwise losses*

→ *fertilisation at timepoints of high losses is prohibited*

Fertilisation Ordinance (2017) – general points

- Determination of nutrient demand required for N and P
- Soil analysis not necessarily required (only advised) but at least official values for each year necessary
- Nutrient content of own organic fertilisers not necessarily required (standard values ok)
- Organic fertilisation: 170 kg N ha^{-1} max. (Per total area of farm, single fields may receive more)
- General fertilisation prohibition of liquid organic fertilisers during 01.Nov. – 31.Jan.
- Farmyard manure: 15.Dec – 15. Jan.
- Storage capacity for organic fertilisers of 6 months
- In grassland application techniques with low emission (e.G. Trailing shoe, injection) required from year 2025
- Adapted distances to surface water bodies, new regularies for frozen, wet and snow covered soils and fertilization after harvest of cereals in autumn
- N balance until 2020: 60 kg N ha^{-1}, then 50 kg N ha^{-1} (P: 20 and 10 kg P ha^{-1}, respectively)
- **Novelled N demand** values for crops as function of yield (how measured in grassland?)
- **Grassland**: n demand of e.G. 245 kg N ha^{-1} for 4-cut system → subtraction due to
  - Delivery from organic fertilization of preceding year (10% of totally applied organic N)
  - N delivery from soil as function of humus content (e.G. <8% humus = 10 kg N ha^{-1})
  - N delivery by legumes (e.G. 10% legumes = 20 kg N ha^{-1} $year^{-1}$)

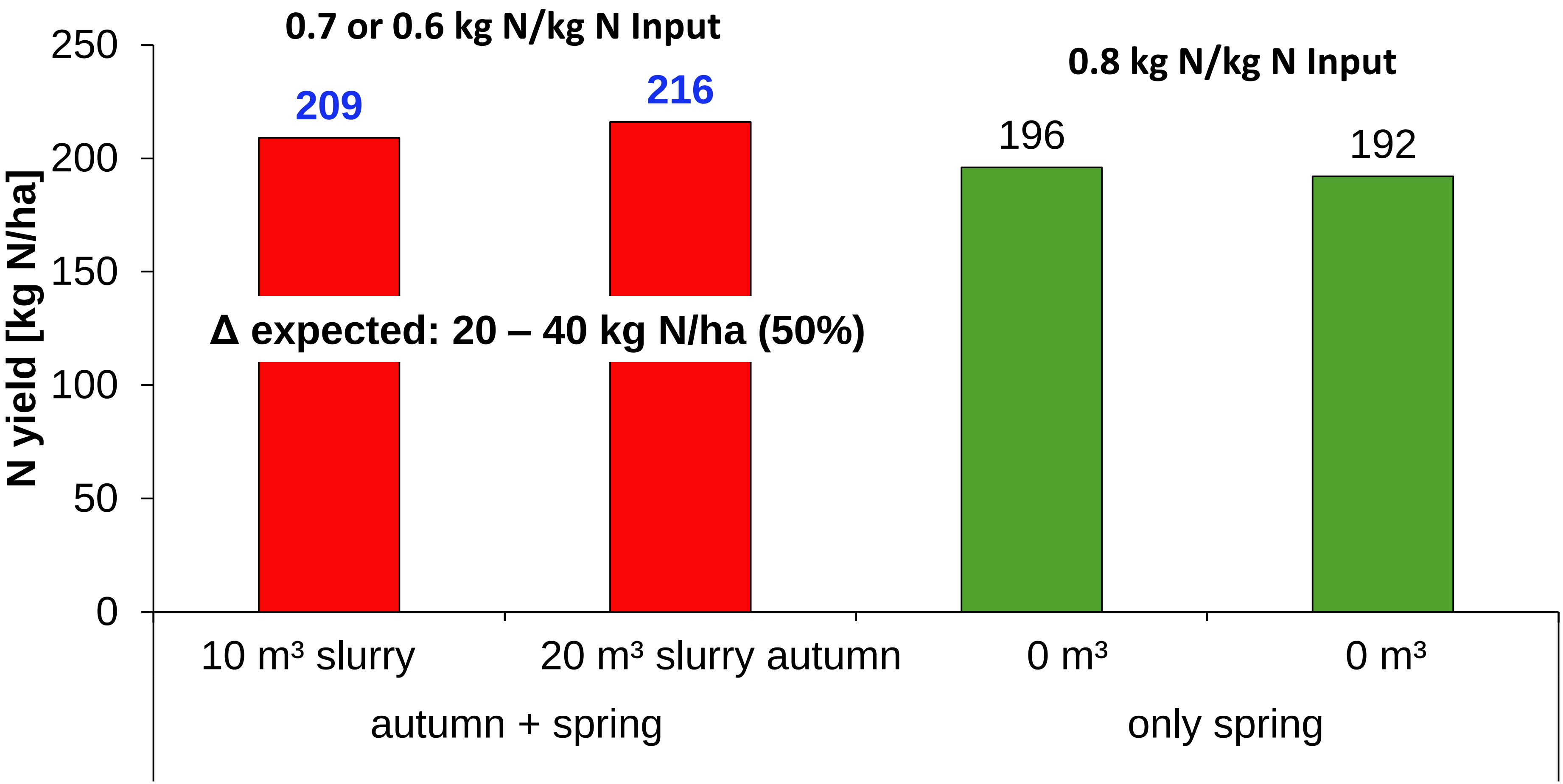
Consequences for grassland fertilisation

→ *higher* ***N*** *utilisation required*

→ *no slurry application after last cut in the year*

→ *(only application techniques and adapted timepoints to increase nutrient utilisation)*

Nitrogen yields of grassland with or without additional autumn slurry application in northern Germany on sandy soil (average 2004-2006)



(Lausen & Biernat, 2017)

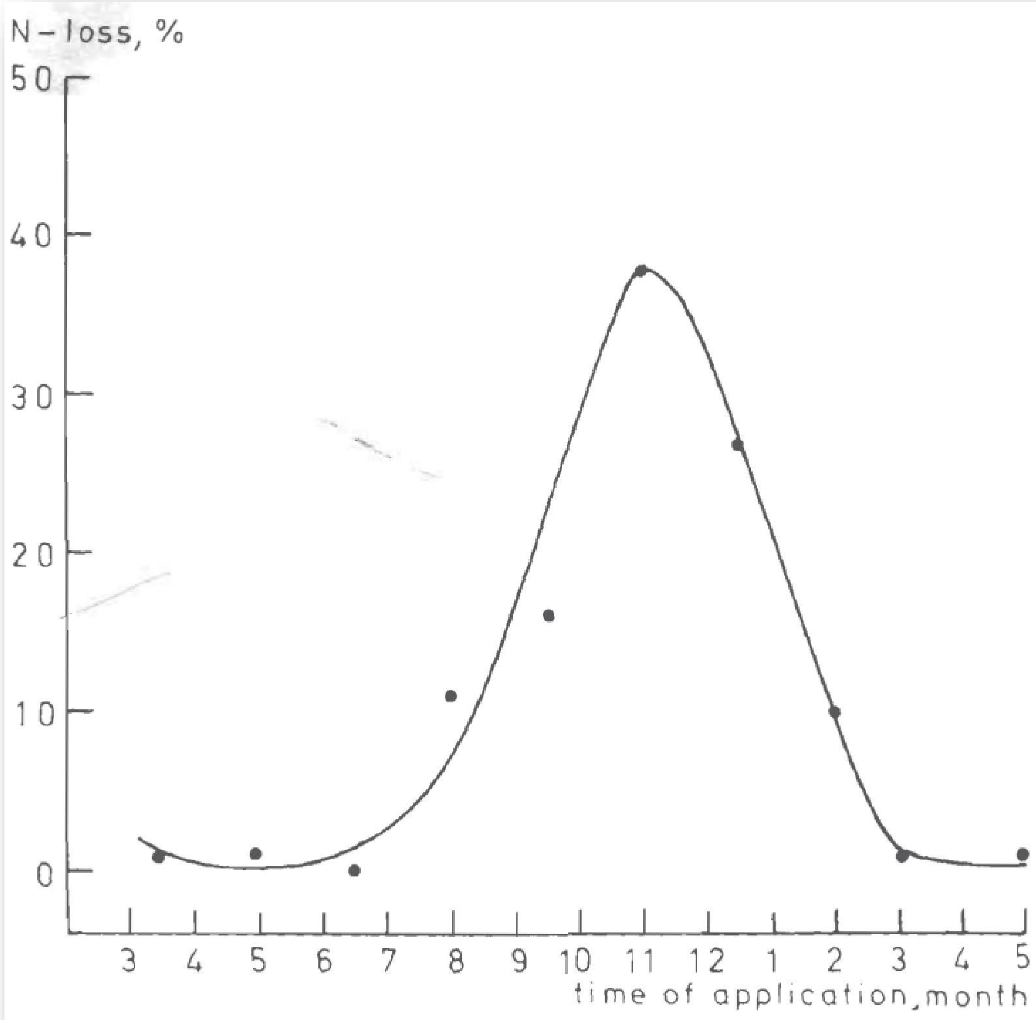
Nitrogen yields of grassland with or without additional autumn slurry application in northern Germany on sandy soil (average 2004-2006)

Treatments compared were:

- Autumn slurry treatments received additional slurry, i.E. 40 or 80 kg N ha^{-1} additionally
- Treatments + slurry autumn higher yield of **~10 or 20 kg N ha^{-1}**
- With efficient utilisation of at least 50% of the N in the slurry, the difference between autumn and spring treatments should range **at 20 or 40 kg N ha^{-1}**
- Consequently only **25% utilisation, i.E. 1 kg N m^{-3}**
- Utilisation marginal to low → expensive additional N yield

→ ***Slurry application after last cut in the year with negative consequences for environment and €***

→Slurry application prior to leaching period results in higher losses and lower plant available N



(Kolenbrander et al., 1981)

→Slurry application prior to leaching period results in higher losses and lower plant available N

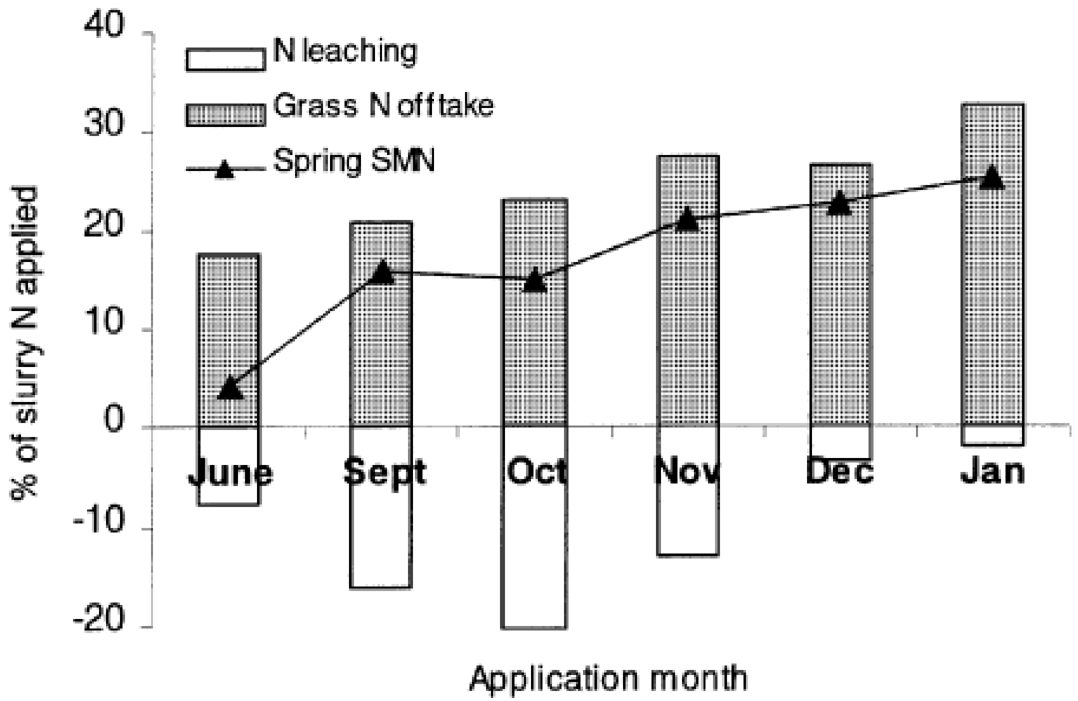


Figure 3. Effect of slurry application timing on average N leaching losses, N recovery in harvested silage grass and spring SMN, all expressed as % of slurry N applied; mean results from the four experimental sites, 1990/91 – 1993/94 (15 site years of data represented).

(Smith et al., 2002)

→ compensation by mineral fertilisation restricted due to N demand values

→Slurry application prior to leaching period results in higher losses and lower plant available N

Table 2. Diffuse water pollution and soil compaction risks following slurry applications to free draining soils

Timing	Nitrate-N cereals grass & oilseed rape	Ammonium-N	Phosphorus	Microbial pathogens	Soil compaction
Autumn (Aug-Oct)	★★★/★★	★	★	★	★
Winter (Nov-Jan)	★★	★★	★★	★	★★
Spring (Feb-Apr)	★	★	★	★	★
Summer (May-Jul)	★	★	★	★	★

★ low risk, ★★ medium risk, ★★★ high risk

(ADAS, 2013)

→Consequences of low N utilisation for nutrient balances on grassland

<u>low efficiency due to autumn slurry on average 40% of the slurry N</u>

N Input	4 cuts, sandy soil	
N demand	kg N/ha	218
Organic N 170 kg/ha * 40%	kg N/ha	68
mineral N	kg N/ha	150

N balance	kg N/ha
mineral N	150
*N from slurry	128
N yield grass	198
N balance	80

<u>high efficiency (modern technique, no autumn slurry) of 70%</u>

N Input	4 cuts, sandy soil	
N demand	kg N/ha	218
Organic N 170 kg/ha * 70%	kg N/ha	119
mineral N	kg N/ha	99

N balance	kg N/ha
mineral N	99
*N from slurry	128
N yield grass	198
N balance	29

- refers to **Fertilisation Ordinance, where 75% of slurry N are taken into account for N balance**
- **target N balance 50 - 60 kg N ha^{-1}**

Costs and benefits of N fertilisation

(Van Grinsven et al. 2013)

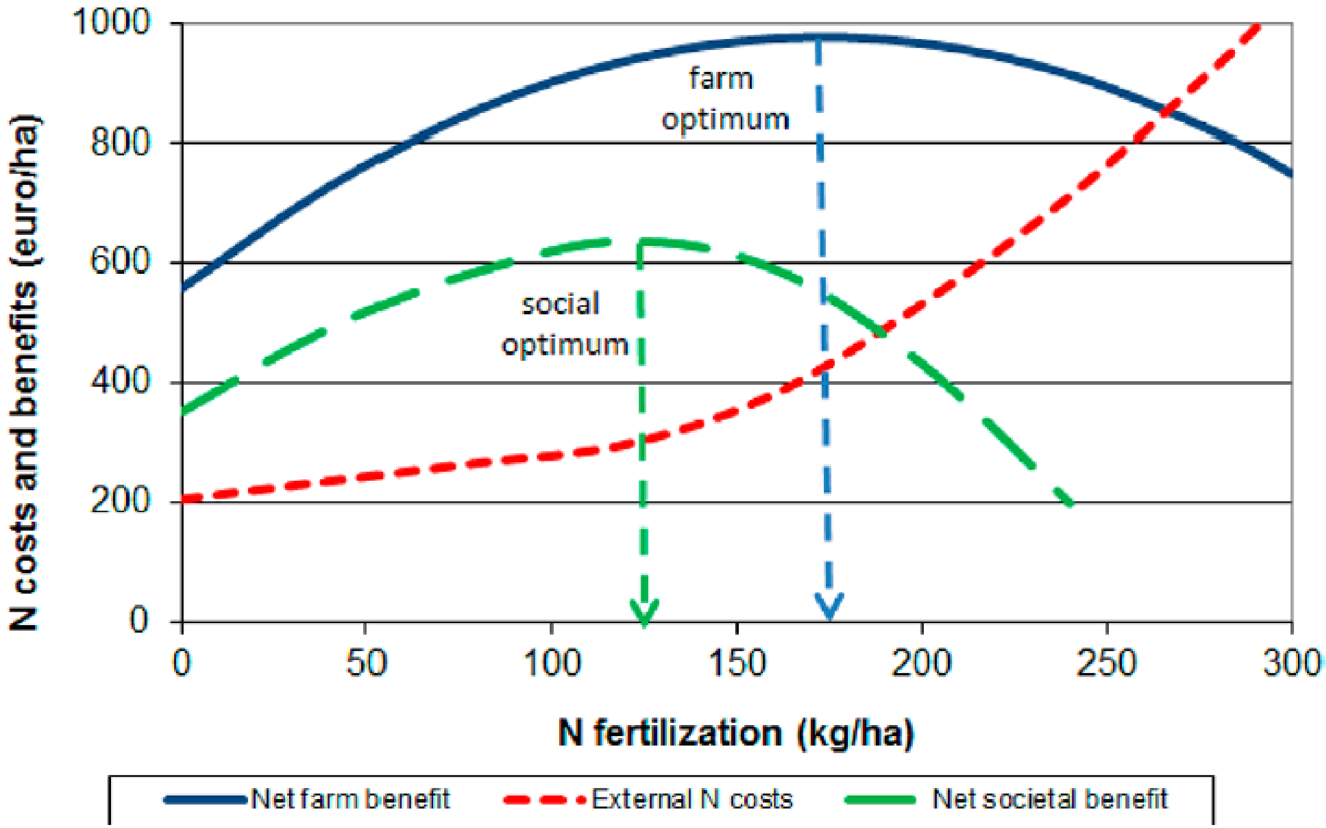


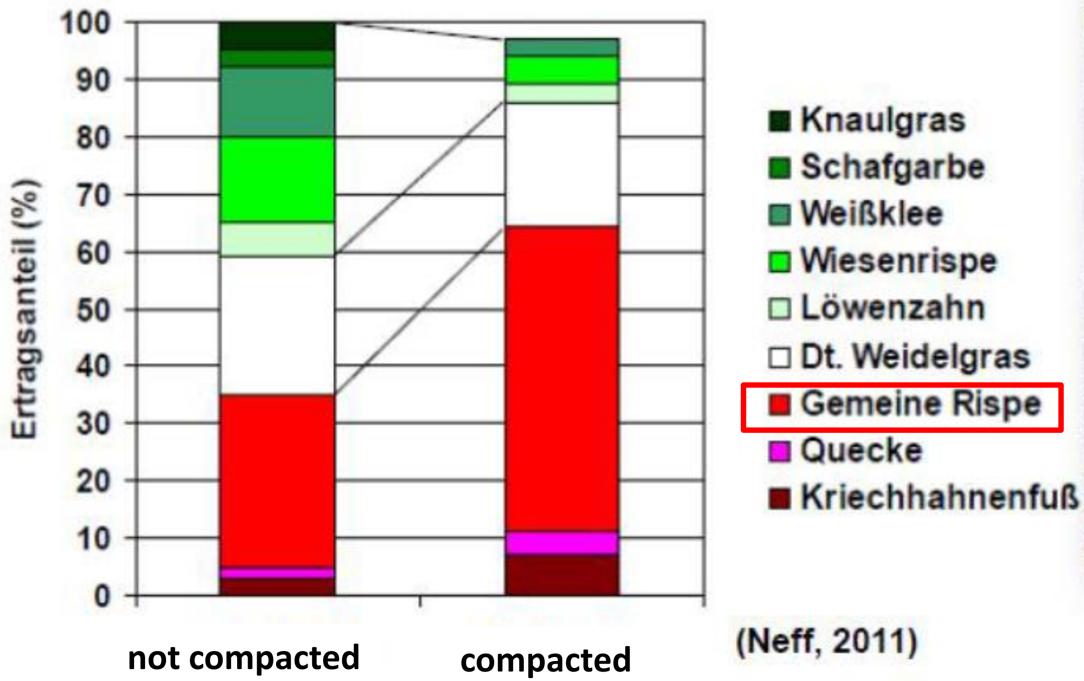
Figure 5. Benefits and costs of nitrogen fertilization (CAN) on winter wheat. (N response based on Henke et al.[31] which is representative for German conditions.).

Negative externalities due to unadapted fertilisation management

Other rconsequences of slurry application under moist conditions in autumn

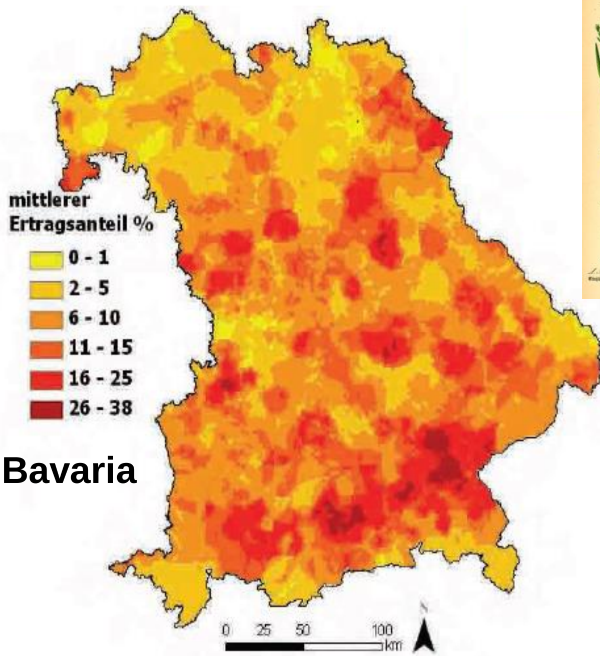
→ sward degradation due to propagation of *Poa trivialis* L. (Gemeine Rispe)

yield share (%) of several species found in the first regrowth in a cut grassland in relation to soil compaction

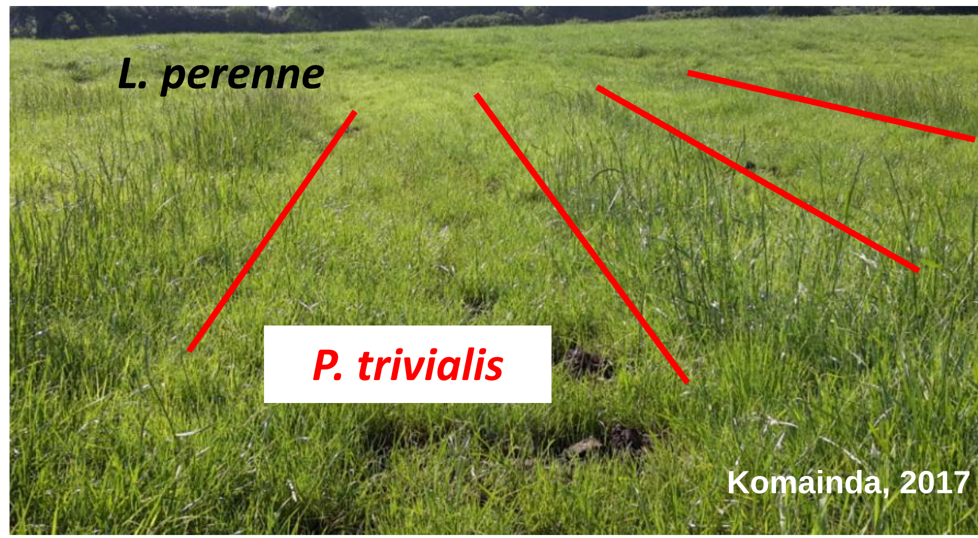


Poa trivialis L. – a problem in intensive grassland?

Primary growth of cut grassland regularly fertilized with slurry in autumn after last cut



First regrowth of cut grassland – differentiation by wheel tracs

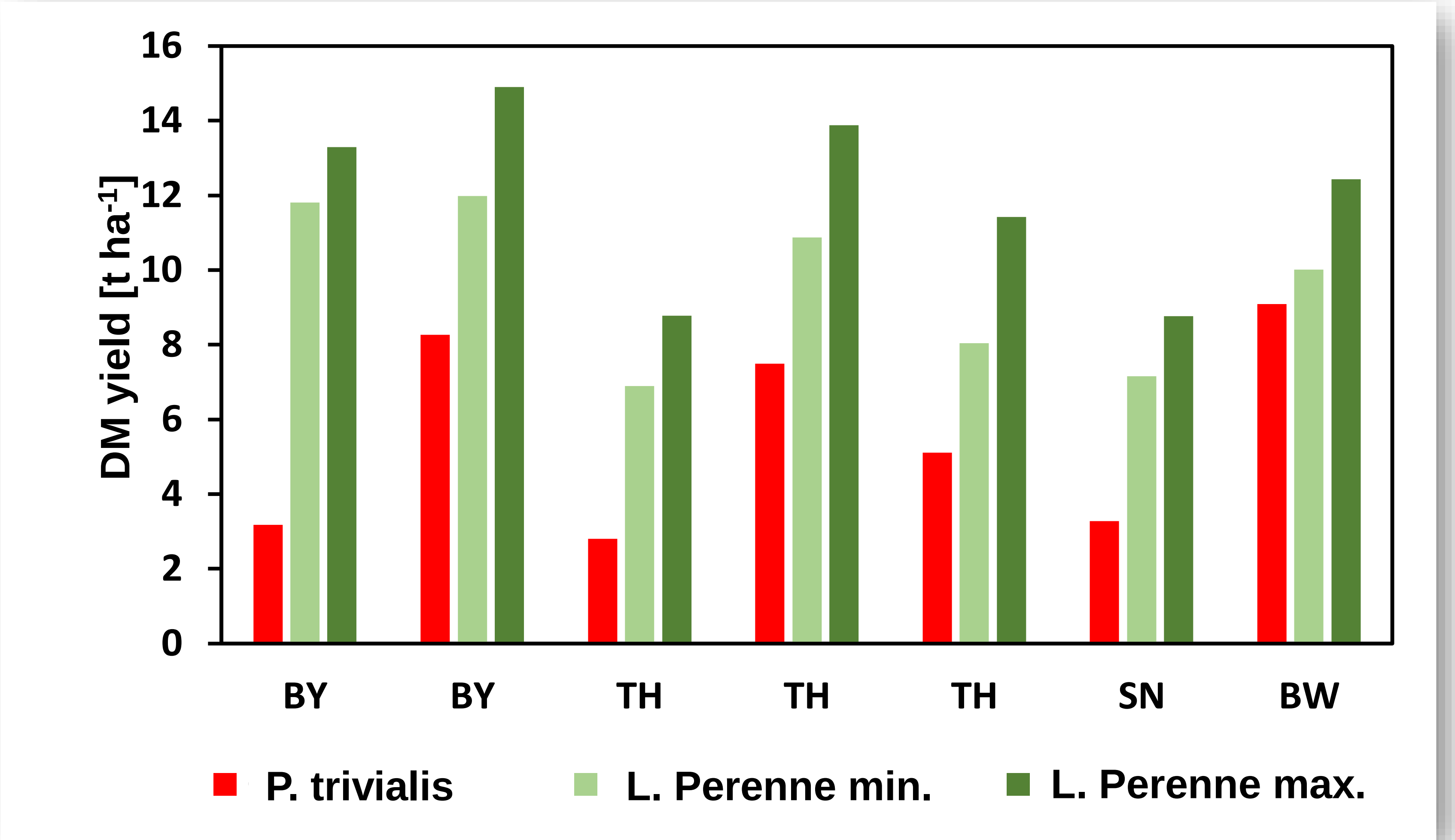


P. Trivialis represents the **second major** grass found in permanent grassland of bavaria during 2002-2008

(Kuhn et al., 2011)

Sward quality grassland – rough bluegrass (*Poa trivialis*)

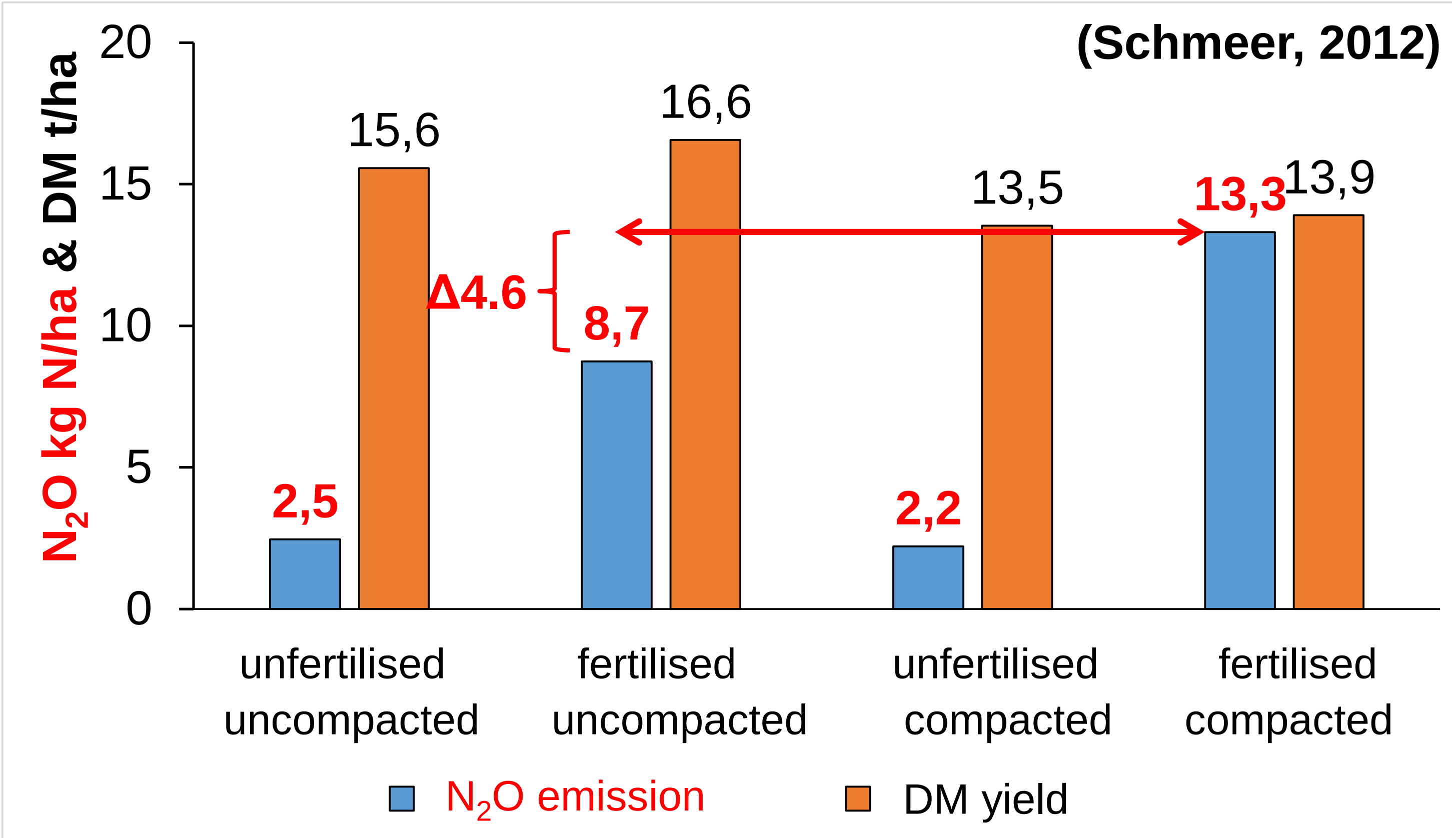
(Hartmann et al., 2011)



Year 2010: 7 sites (BY: bavaria, TH: thuringia, SN: saxony-anhalt, BW: baden wuerttemberg; 40 varieties of *L. Perenne*

- *P. Trivialis* yields only ~**50%** compared to ***L. Perenne***
- High share in sward consequently reduces **nutrient utilisation** **(fertilisation law!)**
- Swards with a share of *p. Trivials* between **20 to 25 %, i.E. Yield losses of 10 – 12%** should be resown with *L. Perenne* under intensive management
- Resowing requires between **150 – 210 € ha^{-1}** in a three-year cyclus
- I.E. Annual additional gain of resowing of between **50 – 70 € required**
- If **1 t DM silage contain between 80 – 100 € of value**
- Resowing should yield between **0,4 and 0,9 t DM ha^{-1} annually**
- Resown swards yield up to 60% higher compared to unsown (hofmann and isselstein, 2004)

Other consequences of slurry application under moist conditions in autumn → soil compaction and increased risk of N_2O emission



- late fertilisation = high risk of soil compaction and consequently N_2O emission (N + reductive conditions in soil)
- eco-efficiency: +N uncompacted vs. compacted +4.6 kg N_2O-N ha^{-1} & -2.7 t DM ha^{-1} =
- **0.5 vs. 0.9 kg N_2O-N t^{-1} DM → late fertilisation with respect to climate critical**

Further options for higher N utilisation in grass and forage production – home made proteins?

→ cultivation of legumes
→ problem: forage production frequently on light sandy soils with low pH
→ performance of alfalfa (*Medicago sativa* L.)?

pH soil = 7 → liming
rhizobia inoculation necessary

Generally:

- soil samples
- 0.4 – 0.5 kg S dt^{-1} DM yield)
- 1 kg ha^{-1} B
- cold soils max. 40 kg N ha^{-1} as starter

Options of sowing
Understorey in cereals

- 15 – 25 kg ha^{-1}
- before shooting (BBCH 32)
- diagonal to drilling of cereals

Blank seeding

- End of april until august
- 25 – 30 kg ha^{-1}
- 12 cm row distances

Performance of alfalfa or alfalfa grass on a sandy soil

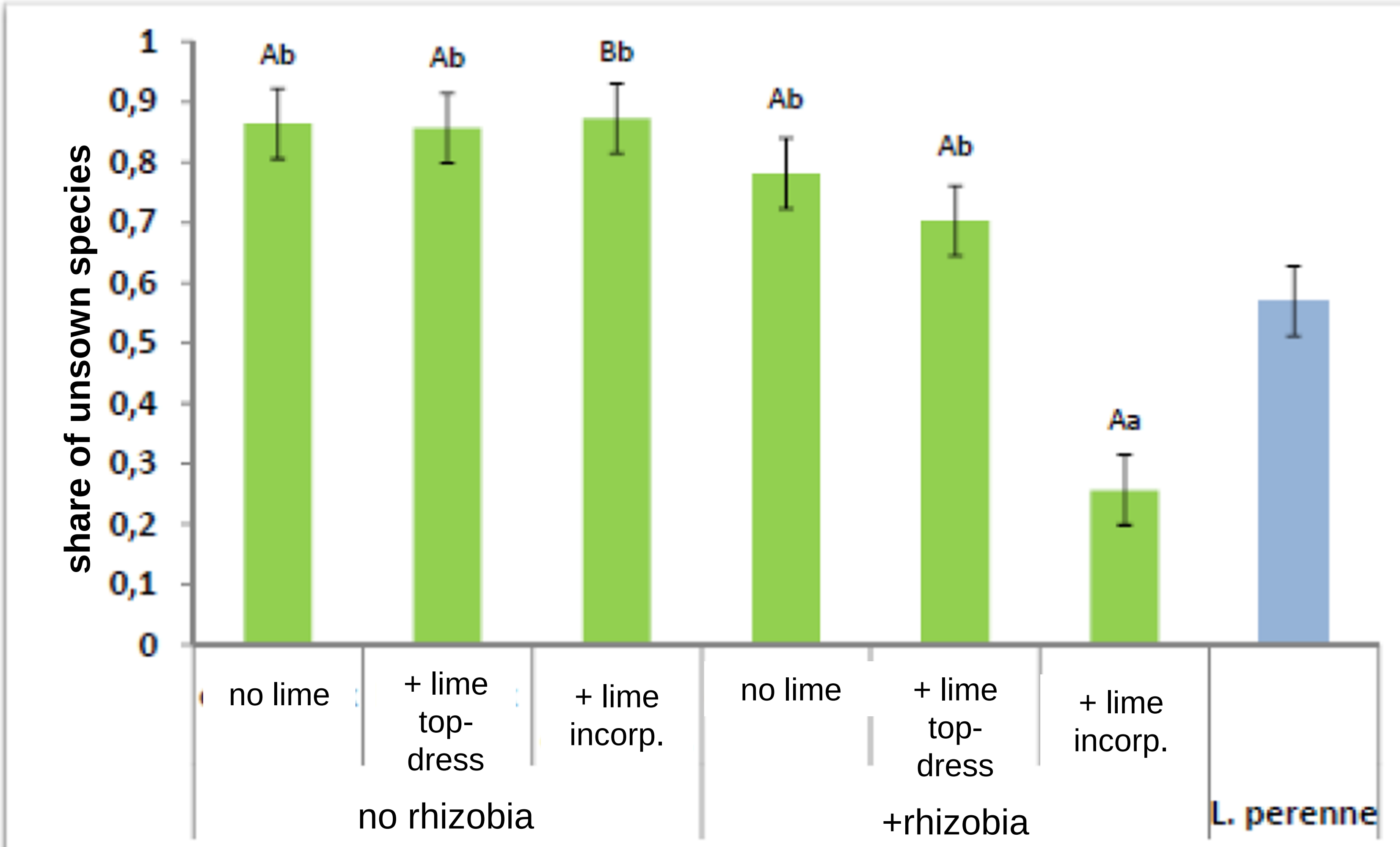
- **Blank seeding end of april with or without inoculation and liming with 15 dt ha^{-1} coccolithic lime**
- Site: Humic Podzol, sandy soil , pH ~ 5

10.07.2014

no lime no rhizobia

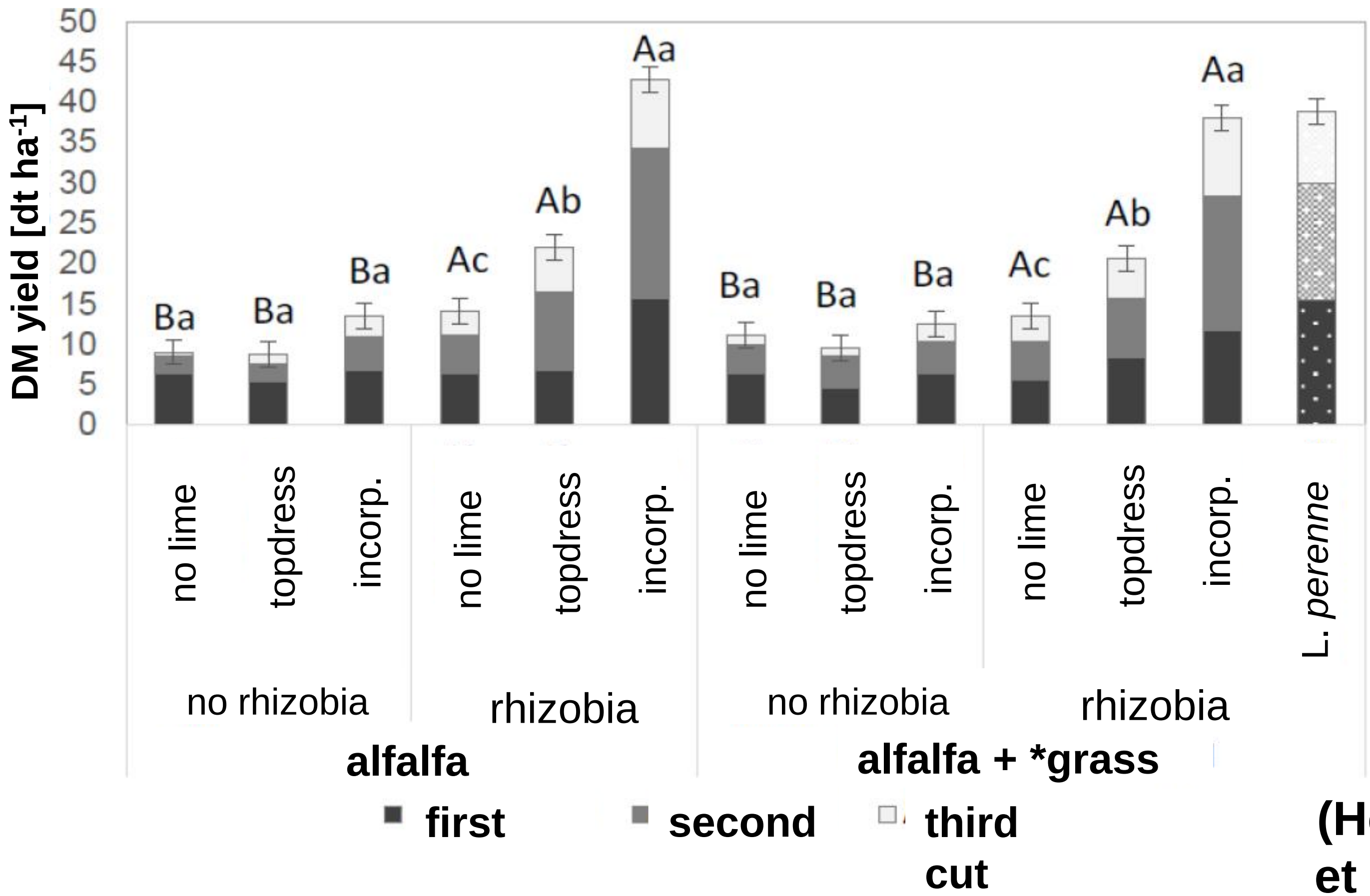
+ lime + rhizobia

Influence on establishment



(Pils, 2015, unpubl.)

Influence of lime application (head or incorporated) and rhizobia inoculation on yield during establishing year (3 cuts)



(Herrmann et al, 2015)

- lime either incorporated prior to seeding or topdressed after seeding
- *binary mixture of alfalfa and tall fescue (*Festuca arundinacea*) (15 and 20 kg ha^{-1} alfalfa and tall fescue, respectively)

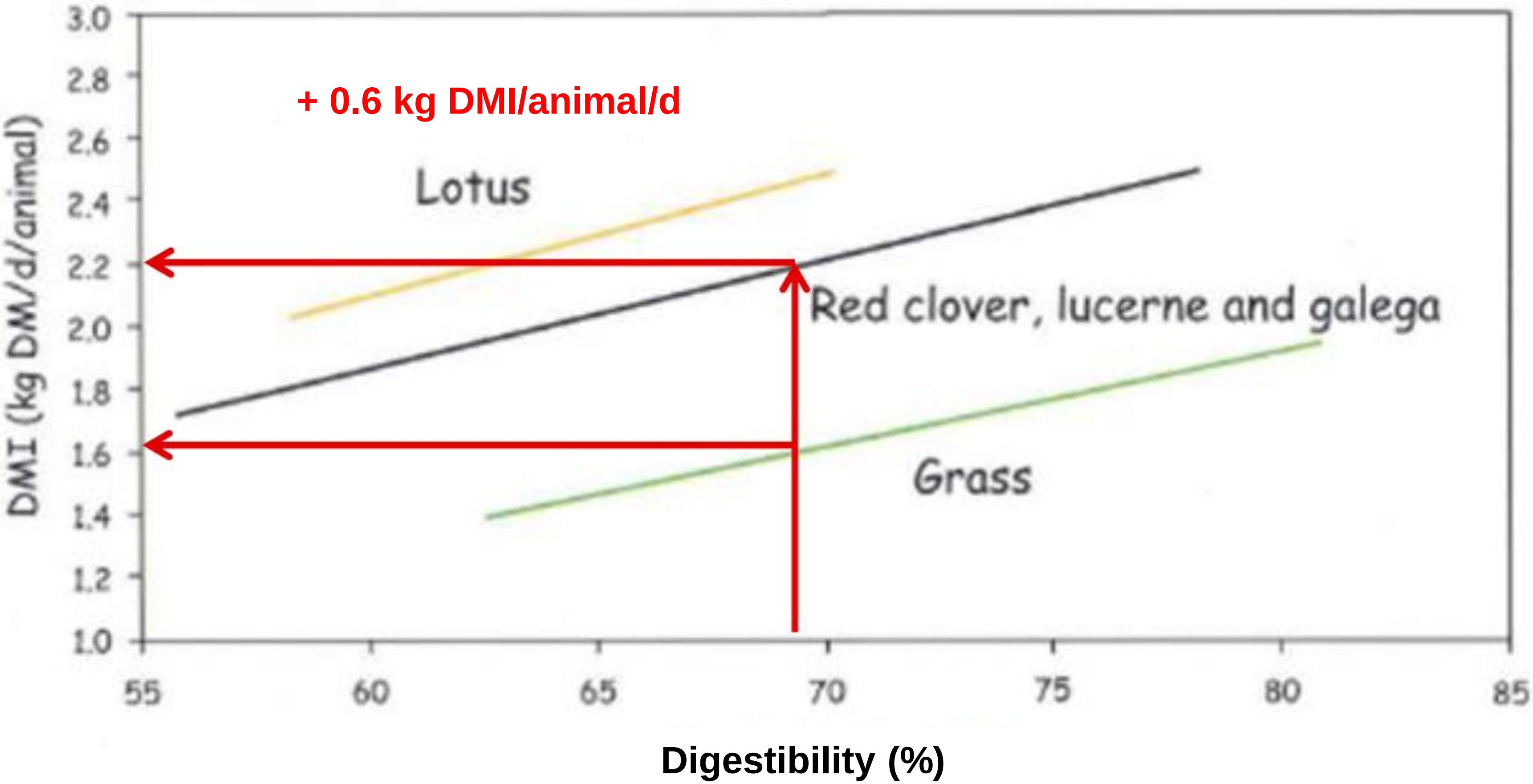
Energy content of alfalfa and alfalfa grass (Bavaria)

Angaben in der Trockenmasse		Luzernesilage Ø 2014	Luzernesilage Ø 2013	Luzernegrassilage Ø 2014	Luzernegrassilage Ø 2013
Anzahl Proben		*38*	*109*	*27*	*73*
Trockenmasse	g	407	398	380	359
Rohasche	g	85	91	85	90
Rohprotein	g	181	172	175	161
nutzb. Protein	g	135	128	133	128
RNB	g	7,4	7,0	6,7	5,3
Rohfett	g	34	31	37	35
Rohfaser	g	261	280	258	270
Zucker	g	51	27	44	25
ADF_{om} 1)	g	338	358	330	343
GB HFT (200mg) 2)	ml	41,6	37,5	43,1	40
NEL	MJ	5,50	5,04	5,78	5,56
ME	MJ	9,3	8,8	9,7	9,5

- average energy concentration **marginal**

(LfL, 2014)

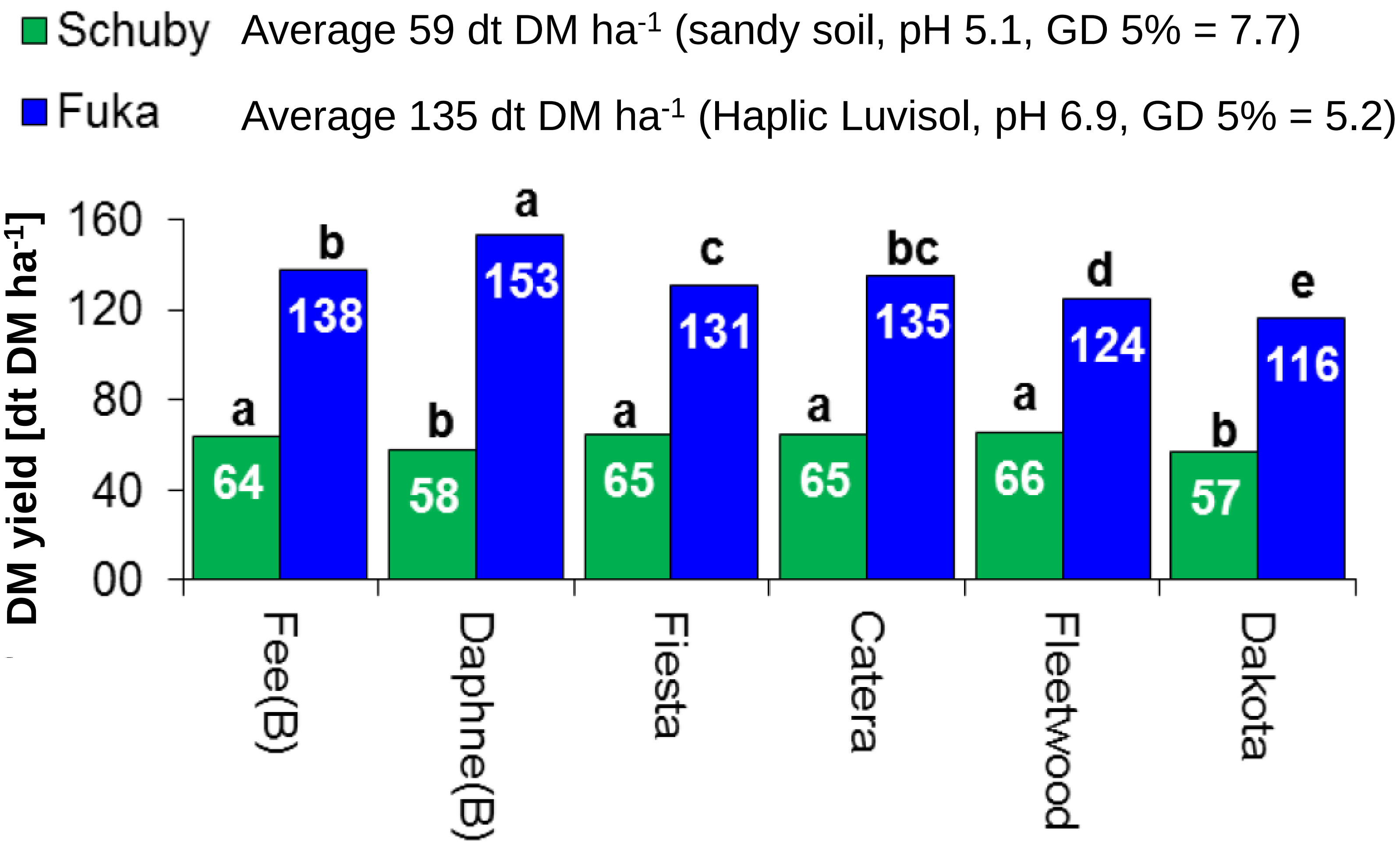
Forage quality – DM intake



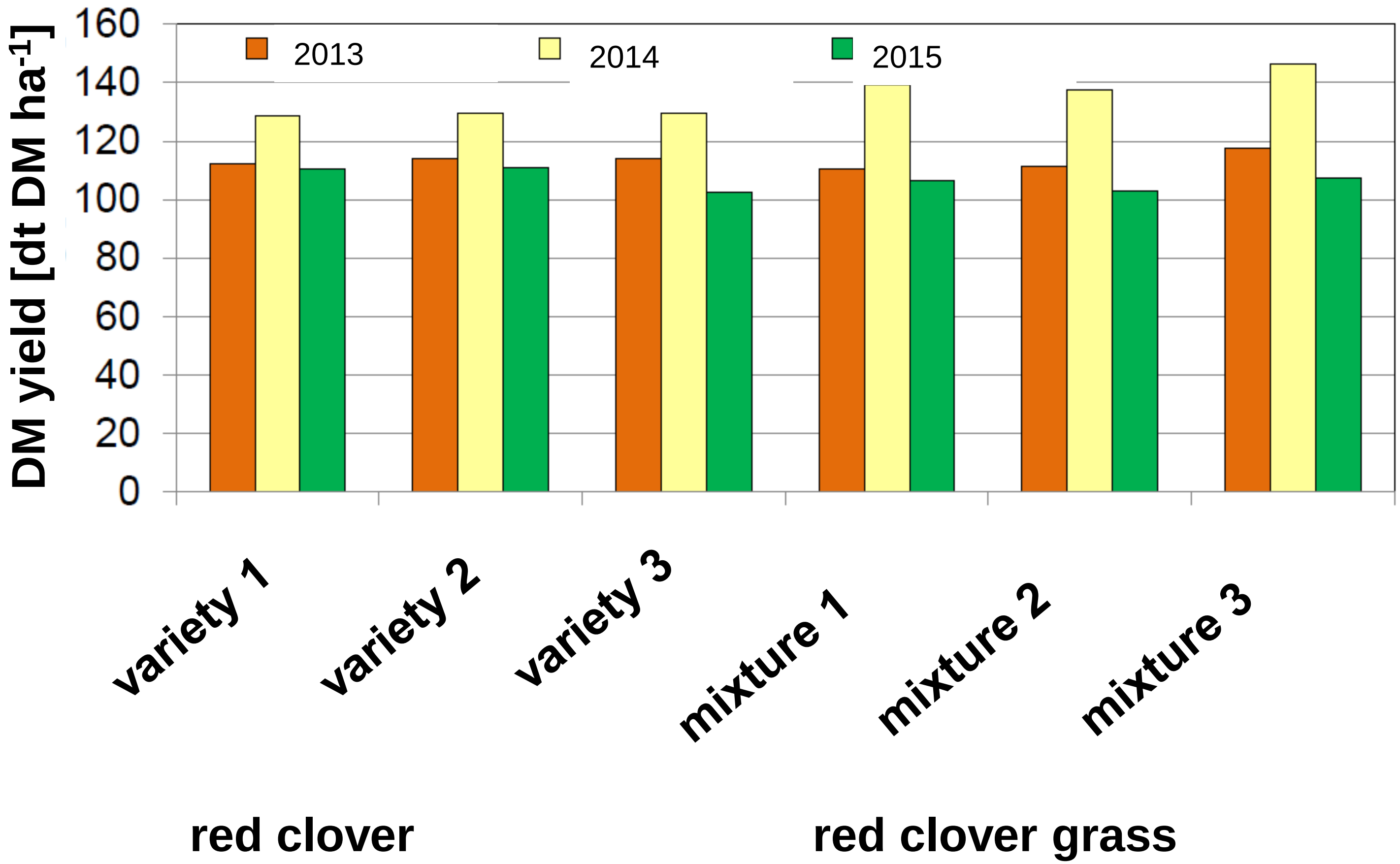
→ High digestibility and therefore high energy intake of legumes, i.E. Alfalfa

(Dewhurst et al., 2003)

Variety trials in Northern Germany – performance on sand?



Alternative legume? *Trifolium pratense*



- mixture 1: 21, 21, 29, 29% italian, hybrid, perennial rygrass, red clover, respectively
- mixture 2: 67 and 33% perennial ryegrass and red clover, respectively
- mixture 3: 17, 33, 17, 20, 13% perennial ryegrass, meadow fescue, timothy, red clover, white clover, respectively

Adaptation for livestock production sites in the northern german plain (sandy soil + low ph)

- On grassland no slurry after last cut (low **N** efficiency, sward degradation + higher **N**$_2$O production)
- Principally alfalfa grown on light sandy soils possible (lime + inoculation with vital rhizobia strains necessary)
- Very good forage quality + high **N** contents (up to 350 kg N ha^{-1} year^{-1})
- Performance good to marginal – red clover more adapted (>100 dt DM ha^{-1})
- **No fertilization** required
- Option for farms with problems to fulfill nutrient balances (‘*homegrown protein*’)

Poland

KATEDRA ŁĄKARSTWA I KRAJOBRAZU PRZYRODNICZEGO Uniwersytet Przyrodniczy w Poznaniu

Department of Grassland and Natural Landscape Sciences

Inno4Grass

Poznań University of Life Sciences

Effective use of permanent grassland in the feeding of dairy cows in Poland

Piotr Goliński

Barbara Golińska

Artur Paszkowski

Utilized agricultural area in Poland (thous. ha)

	1990	2000	2005	2010	2017
Arable land	14388	13940	12220	10428	10757
of which Temporary grassland	n/a	n/a	n/a	n/a	414
Permanent meadows	2475	2503	2528	2629	2796
Permanent pastures	1585	1369	859	654	375

Own elaboration based on GUS, 2018

Location of permanent grassland (PG) in Poland based on remote sensing

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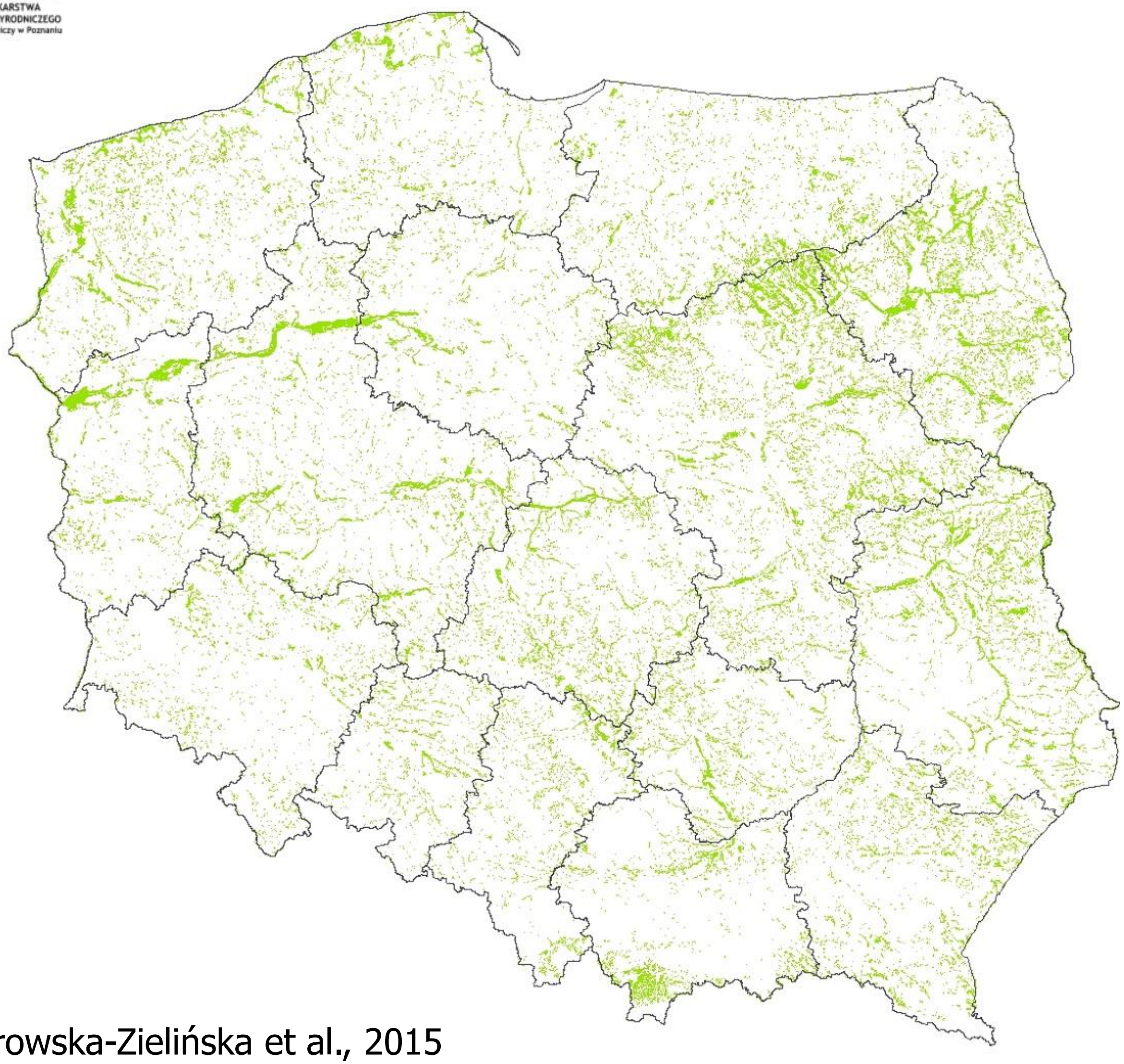
Inno4Grass



Dąbrowska-Zielińska et al., 2015

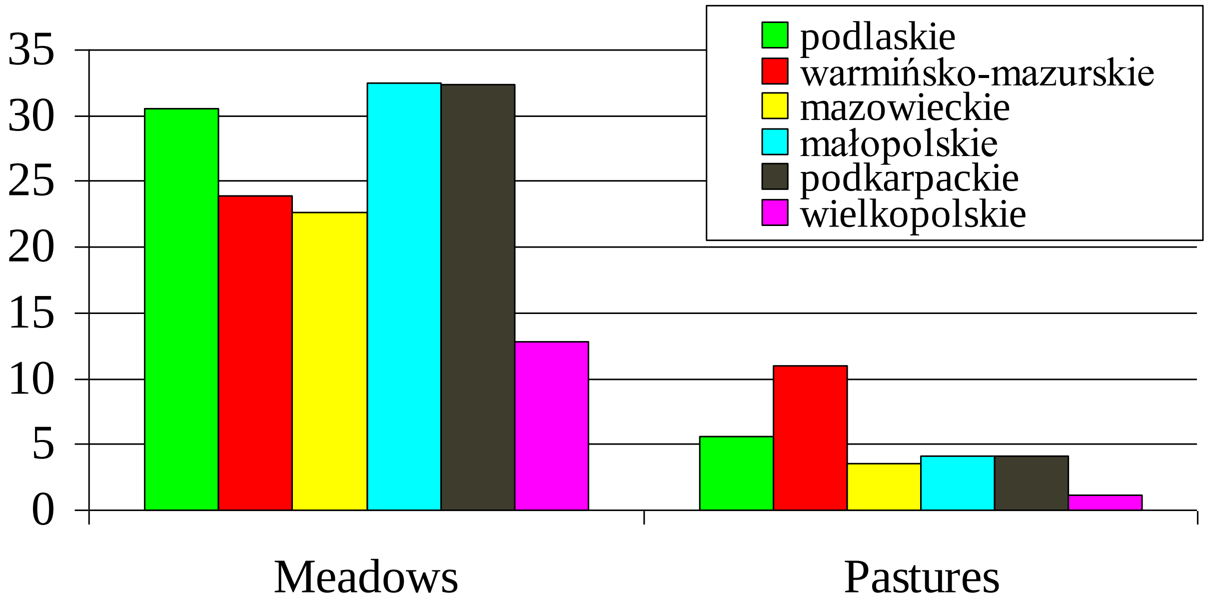
Area of PG
3.17 mln ha
GUS, 2018

Share of PG in AUA
21.7%
GUS, 2018

High habitat and physiographic diversity, limiting the intensity of their use

Intensive PG producing good fodder - around 50% of the area
Extensive PG, natural and semi-natural meadows and pastures - about 50% of the area

Share of permanent grassland in structure of UAA in selected voivodships (%)



Own elaboration based on GUS, 2018

Stock of cattle and dairy cows in Poland (thous. heads)

	1990	2000	2005	2010	2017
Cattle	10049	6083	5483	5742	6143
of which Dairy cows	4919	3098	2755	2529	2153

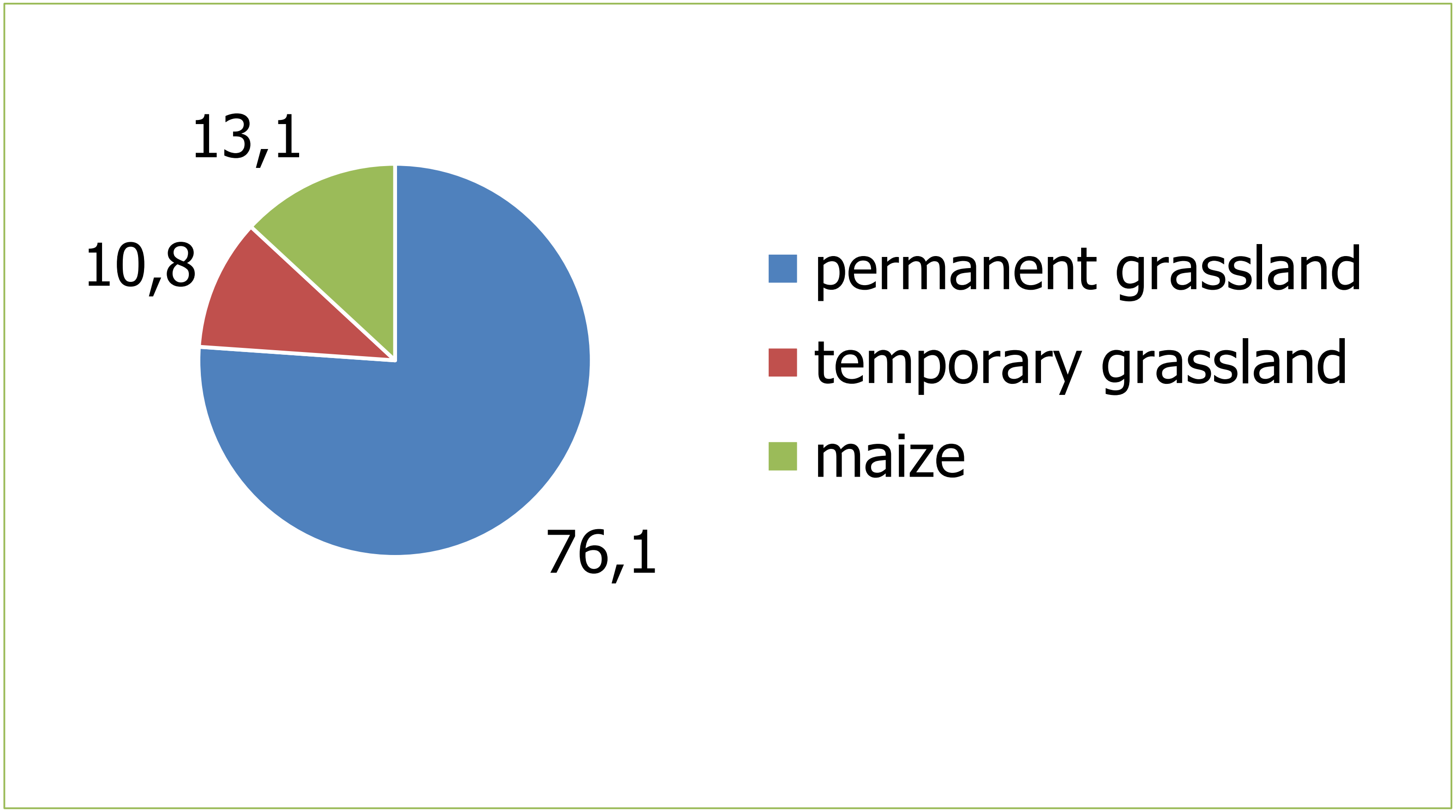
Own elaboration based on GUS, 2018

Cow's milk production in Poland

	1991-95	2000	2005	2010	2017
Milk production (bn kg)	15.40	11.49	11.58	11.92	13.31
Average annual quantity of milk per cow (kg)	3083	3828	4147	4487	5687
under milk recording (kg)	4209	5379	6508	6980	7771

Own elaboration based on GUS, 2018

Structure of fodder area in Poland (%)



Own elaboration based on GUS, 2018

Production and yield from permanent grassland (2017)

- Meadows – 15.15 thous. t of hay
- Pastures – 1.37 thous. t hay

- Average yield – 5.21 t hay per ha

- Production of hay from the first cut >60% and from the second >50%

Own elaboration based on GUS, 2018

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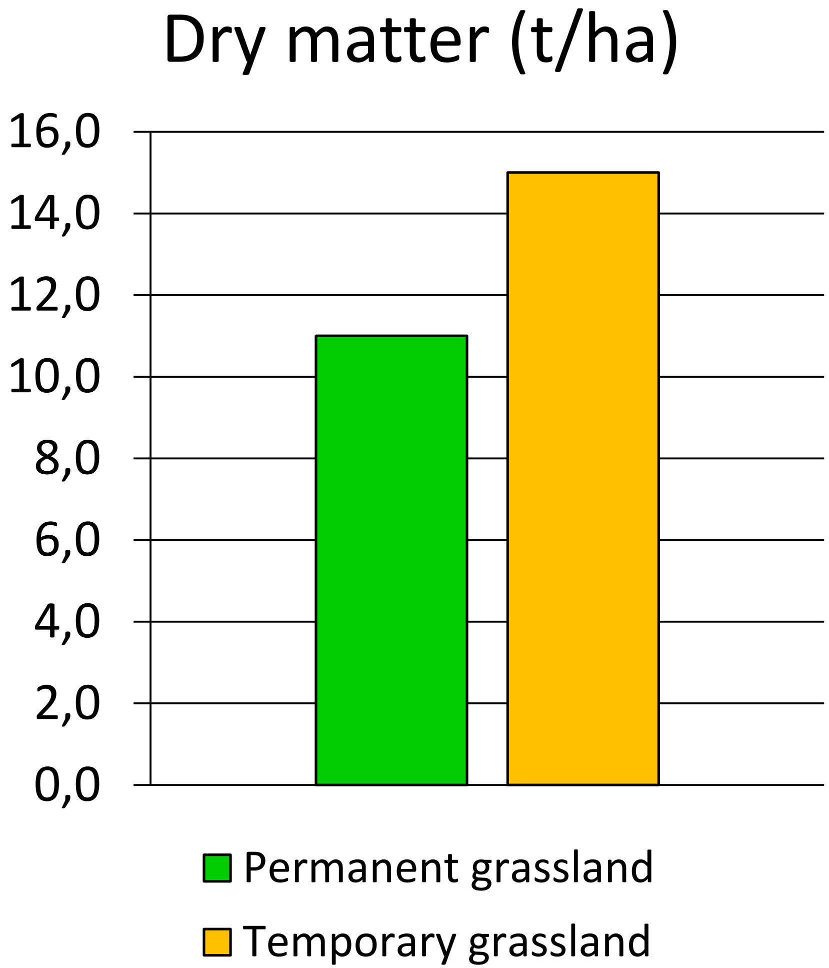
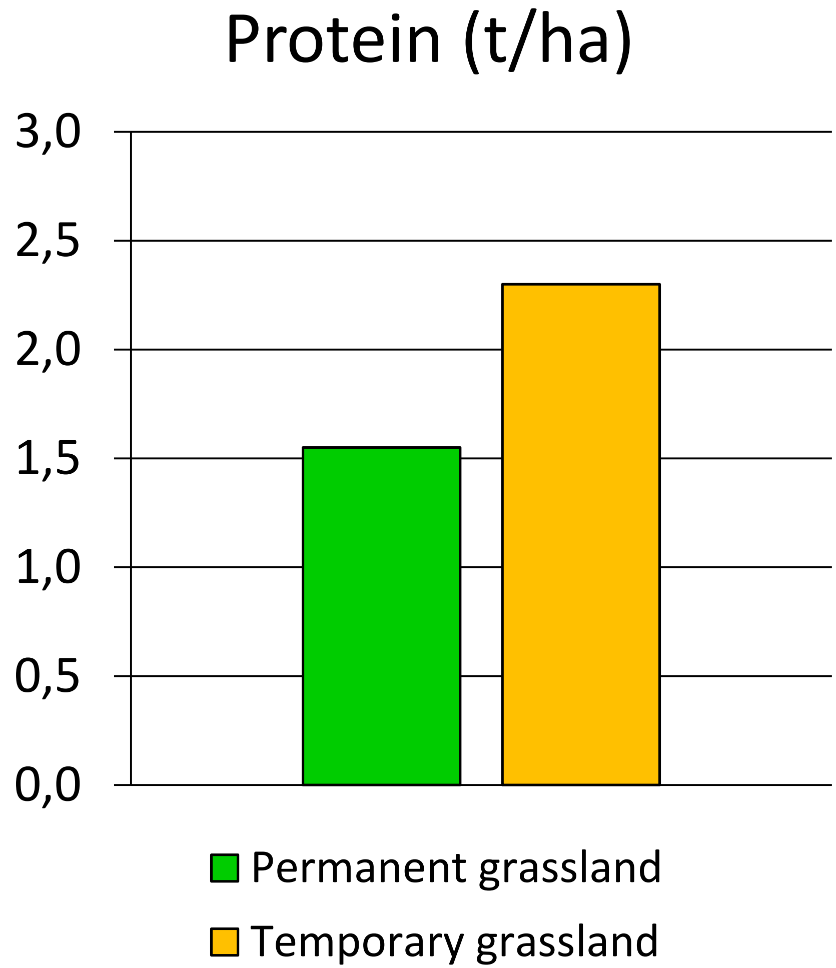
Potential yields from grassland in Poland





Own elaboration based on mutliyear PULS research

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Uniwersytet Przyrodniczy w Poznaniu

Models of milk production in terms of the fodder use from grasslands

- intensive milk production using TMR/PMR system with important role of silage/haylage from permanent/temporary grasslands (milk yield 10000-12000 kg per cow), HF breed
- low-cost technology of milk production with very important role of pasture and/or silage/haylage from permanent/temporary grasslands (milk yield 7000-8000 kg per cow), HF breed and/or dairy cattle breeds adapted to grazing
- pro-ecological/ecological milk production with crucial role of pasture and/or hay from permanent/temporary grasslands – feeding without silage (milk yield 5000-7000 kg per cow), dairy cattle breeds adapted to grazing

Photographs Piotr Goliński

Fodder from grasslands in the intensive milk production

- supplementation of the ration using in TMR/PMR feeding system
- high quality silage/haylage from permanent/temporary grasslands
- large expenditures on fodder production from permanent/temporary grasslands
- regularly renovation of permanent grasslands

Goal → maximizing milk production

Fodder from grasslands in low-cost milk production

- increasing the share of pasture and/or haylage from permanent/temporary grasslands in the feed ration
- reduction of concentrates in the feed ration
- optimization of inputs for the production of high-quality feeds from permanent/temporary grasslands
- regularly renovation of permanent grasslands

Goal → reducing the unit costs of milk production

Fodder from grasslands in pro-ecological milk production

- grasslands as an exclusive and only source of roughage in the ration
- key role of pasture and/or hay from permanent/ temporary grasslands (feeding without silage)
- regularly renovation of permanent grasslands

Goal → high-quality raw material (hay milk) for its processing into excellent quality dairy products (e.g. PDO products)

Pasture sward is the best feed in cattle feeding in terms of CLA

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- the content of raw fat in the sward is 3-5% of DM
- the fat is composed of PUFA that are subject to isomerization in the rumen (linoleic, α-linolenic, oleic acids) with the participation of bacterias, e.g. *Butyrivibrio fibrisolvens*
- the best composition of PUFA occurs in the summer
- in pasture feeding, the Δ9-desaturate activity increases, which from vaccenic acid intensifies the synthesis of CLA in the mammary gland
- **an alternative to pasture is the inclusion of mown grass sward from permanent and temporary grasslands to compose TMR**

High-quality milk from cows fed by grassland sward

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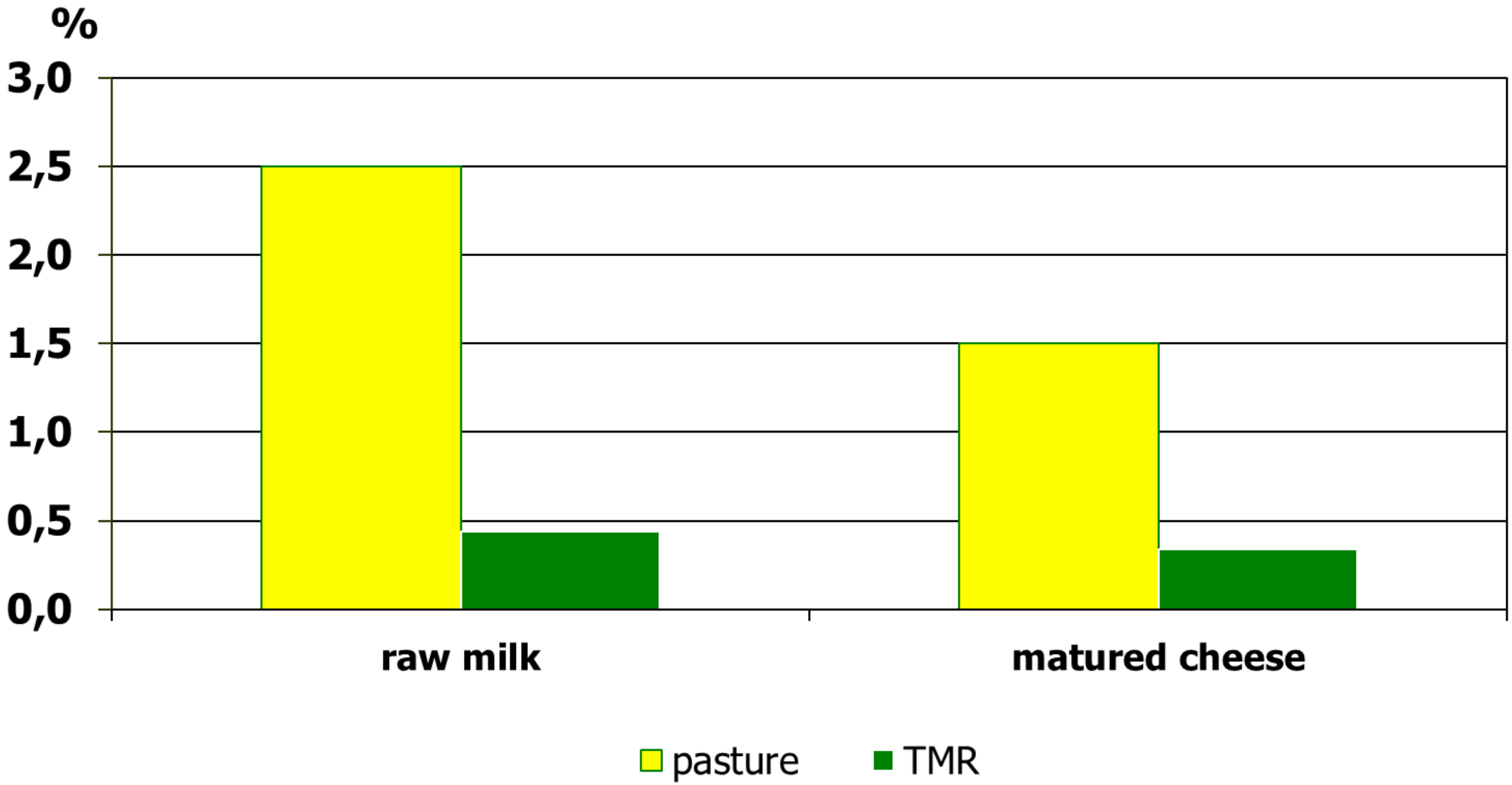
Characteristics of milk from animals grazed on pasture or fed by meadow sward in barns:

- increased content of essential fatty acids (MUFA and PUFA) omega-3 (α-linolenic), omega-6 (linoleic), CLA Iso cis-9 trans-11
- higher content of antioxidants - carotenoids, flavonoids, tocopherols (β-carotene, lutein, active form of vitamin E α-tocopherol)
- better flavour and taste values

Scollan et al., 2005

From grass to glass

CLA content in food products depending on the feeding system (in % of fat)



Khanal et al., 2003

Possibilities of increase the efficiency of fodder production from grasslands for cattle feeding

- application of periodical renovations
- use of valuable species and varieties of perennial forage plants
- optimization of fertilization and sward management
- application of proper irrigation
- optimization of date and time of mowing/grazing the first regrowth
- suitable organization of pasture management
- optimization of sward harvest and forage conservation technology

Grassland renovation and establishment of new grass sward

Strategies and methods for grassland renovation

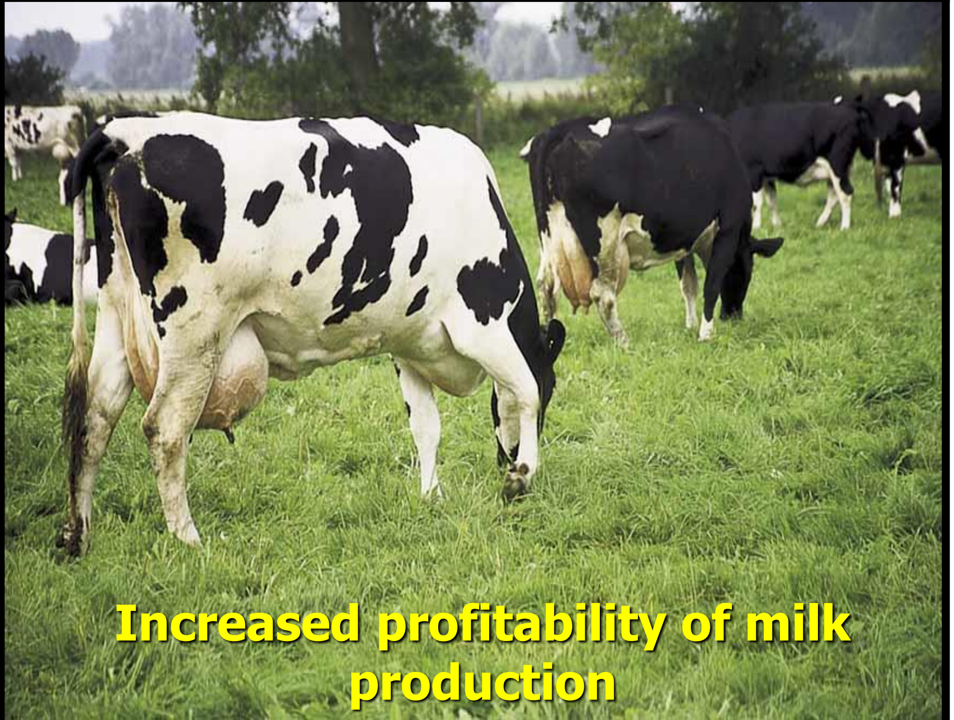
- **Rejuvenation of existing sward without seeds**
  - Fertilization focusing on sward improvement
  - Selective herbicides application
  - Improved sward management
- **Partial sod renovation using seeds**
  - Oversowing or overdrilling
- **Total sod renovation using seeds**
  - Non-selective herbicides and direct drilling
  - Full tillage and drilling or broadcasting

Goliński, 1998

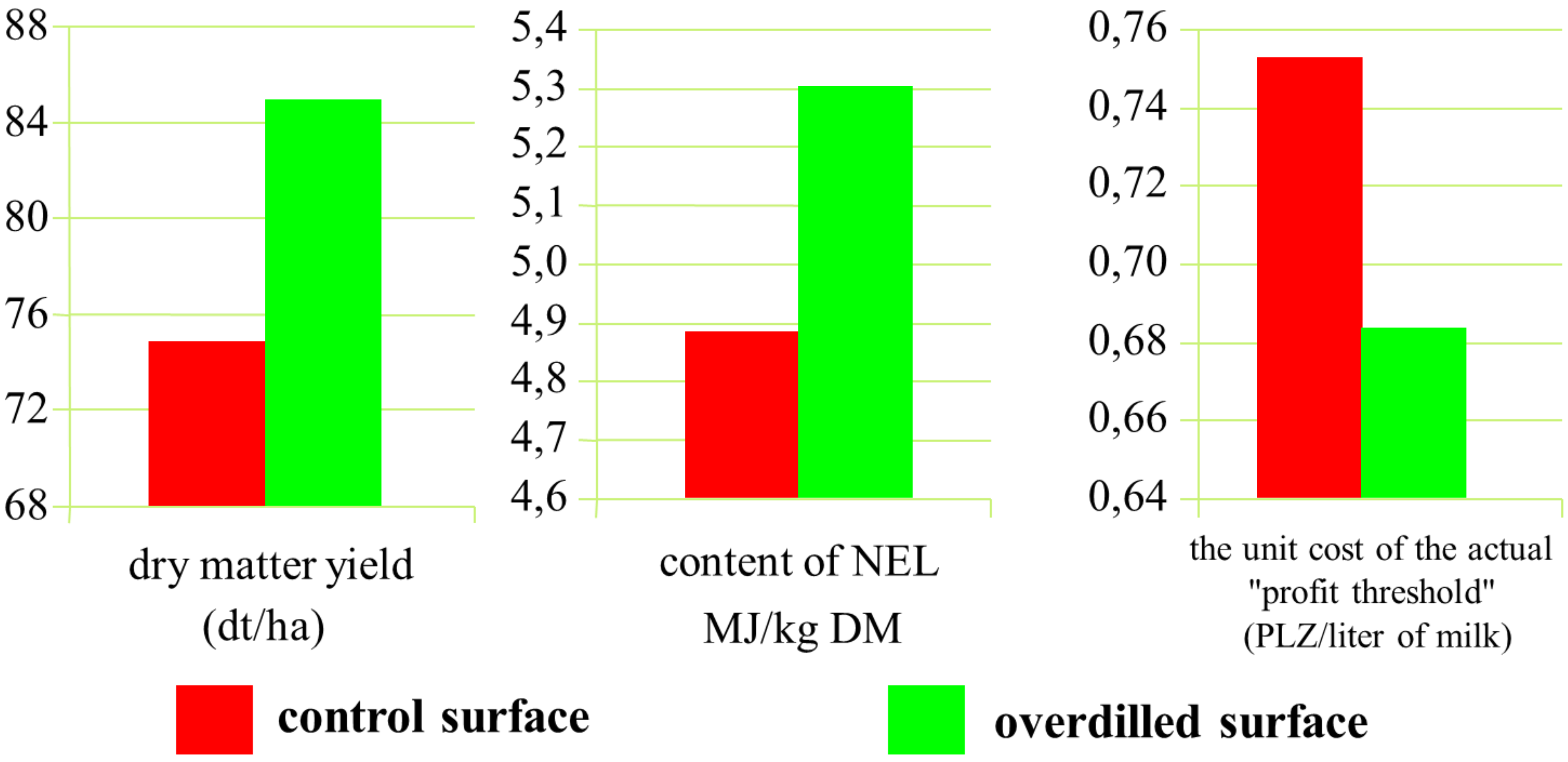

Degraded grassland sward


Renovation using the method of overdrilling
Photographs Piotr Goliński


Effect of renovation – high quality sward

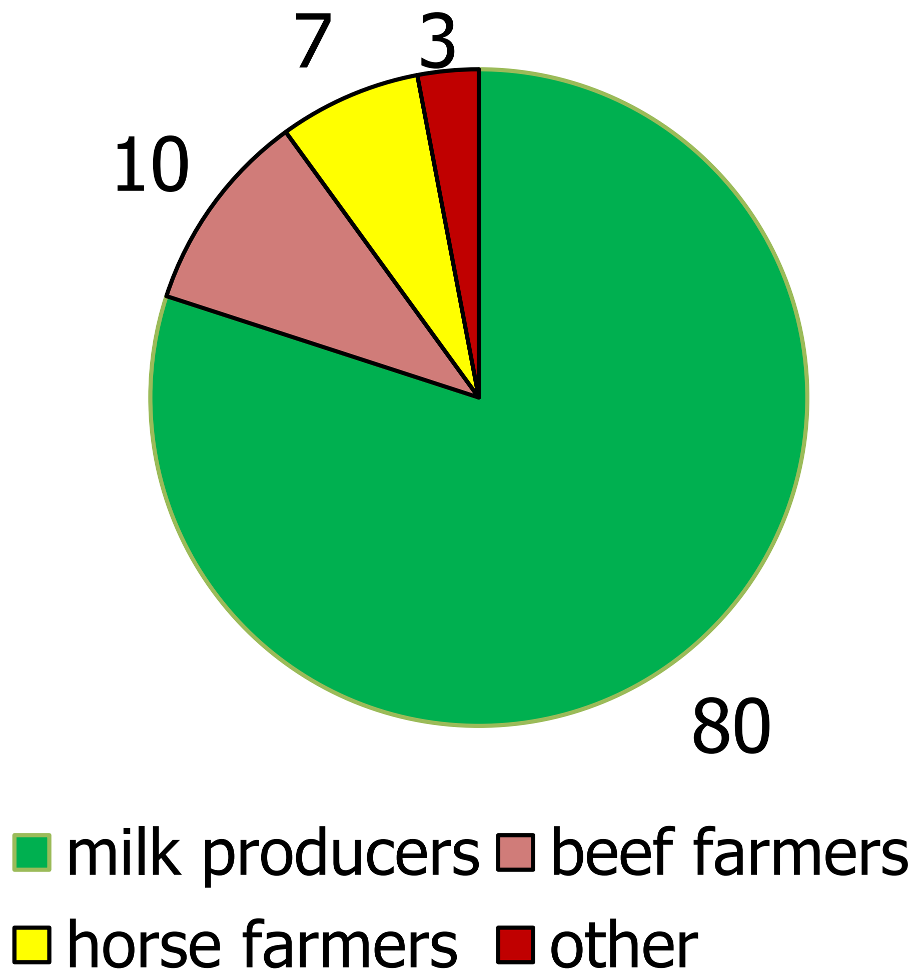

Increased profitability of milk production

Impact of improvement of sward by overdrilling on profitability of milk production



Goliński and Kozłowski, 2000

Structure of the use of biological progress in grass and legumes breeding by type of farmers (%)



Goliński, 2017

Suitability of grasses and legumes for complementary seeding of permanent grasslands

- Grasses: **perennial ryegrass**, meadow fescue (organic soils), hybrid ryegrass, Italian ryegrass, westerwold ryegrass, festulolium
- Legumes: **red clover**, **white clover**, alsike clover (organic soils), bird's-foot trefoil, alfalfa
- Varieties preferred for complementary seeding (the ability to quickly rooting - installation in old sward, high competitiveness)

Goliński, 2018

Suitability of grasses and legumes for mixtures using in total sod renovation of permanent grasslands

- Ranking of the importance of grass species : **perennial ryegrass**, **meadow fescue**, **tall fescue**, **timothy,** **smooth-stalked meadow grass**, **cocksfoot**, **red fescue**, black bent, tall oat-grass, …
- Ranking of the importance of the legume species : **white clover (small-leaved varieties)**, **alsike clover**, **red clover**, bird's-foot trefoil, …

Goliński, 2018

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Suitability of grasses and legumes for mixtures using in set up of temporary grasslands

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- Ranking of the importance of grass species: **Italian ryegrass**, **westerwold ryegrass**, **perennial ryegrass (4n)**, **festulolium**, meadow fescue, timothy, tall fescue, cocksfoot, brome grass, …
- Ranking the importance of the legume species: **alfalfa**, **red clover**, white (large-leaved varieties), alsike clover, crimson clover, persian clover, bird's-foot trefoil, egyptan clover, common sainfoin, …

Goliński, 2018

Strategies of seed mixtures application in the establishment and renovation of grasslands

1. The right selection of the seed mixture from the commercial offers of seed companies

2. Mixtures prepared by an expert, designed depending on the habitat and the direction of grassland use in a specific farm

Characteristics of good quality seed mixture

1. Species composition adapted to habitat and direction of use

2. Use of varieties with high economic value (VCU assessment, post-registration variety testing and variety recommendation into practice)

3. Seeds with high quality parameters (purity, germination)

good seed companies show in the commercial offer what varieties are used in the mixtures

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Selection criteria of the species used for composing the mixtures

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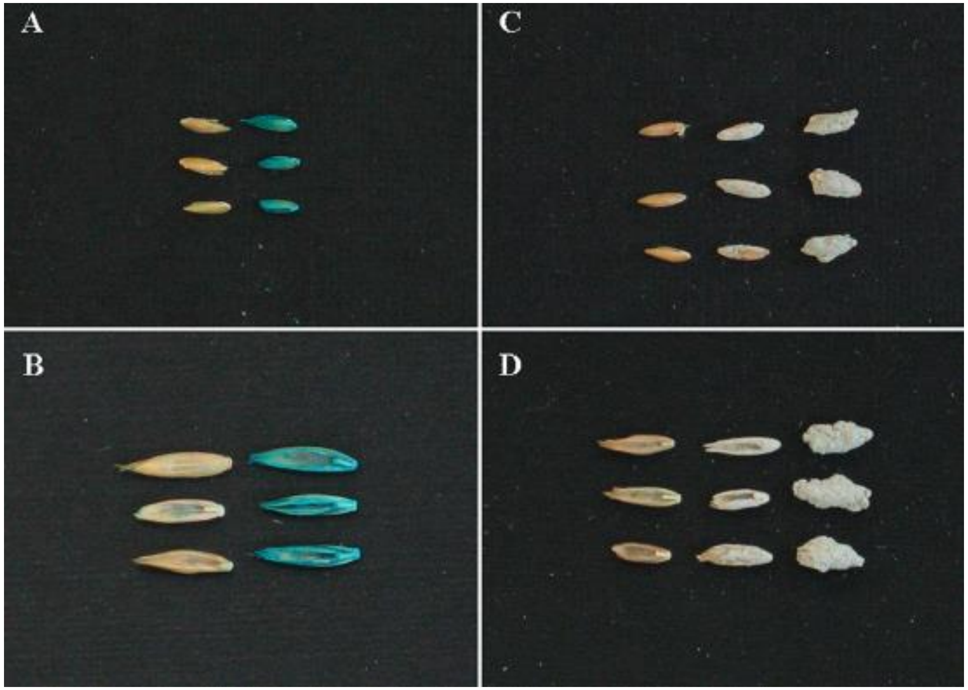
1. Type of use (mowing, grazing, variable)
2. Duration (permanent grassland - PG or temporary grassland - TG)
3. Type of soil (organic, mineral)
4. Humidity of the habitat (optimal, periodically or permanently flooded, periodically or permanently dry)
5. The intensity of nitrogen use
6. Competitiveness of species

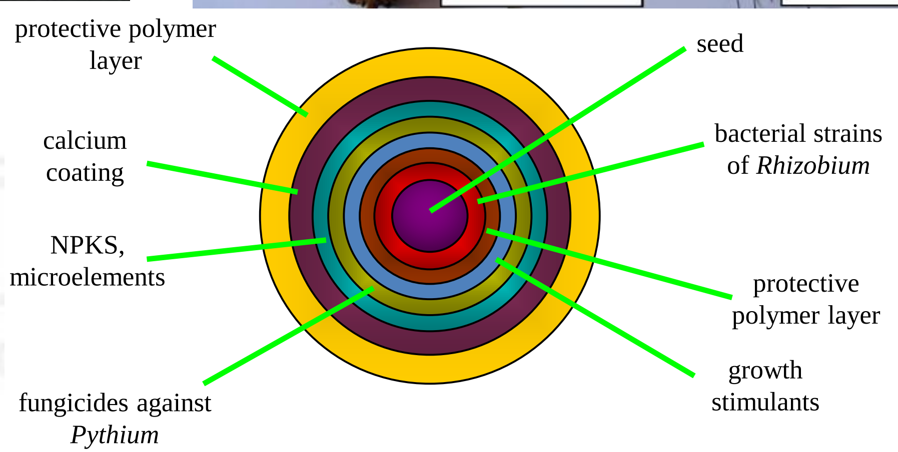
Seed mixtures used in establishment and renovation of grassland

1. Single species (variety) - TG
2. Mixture of several varieties (of different earliness, ploidy) within one species - TG
3. Simple mixture of 2-3 species of grasses or grasses with legumes - TG (PG)
4. Multi-species mixture of grasses or grasses with legumes - PG

Multi-layered seed coating



Photographs companies materials



Sod seeders

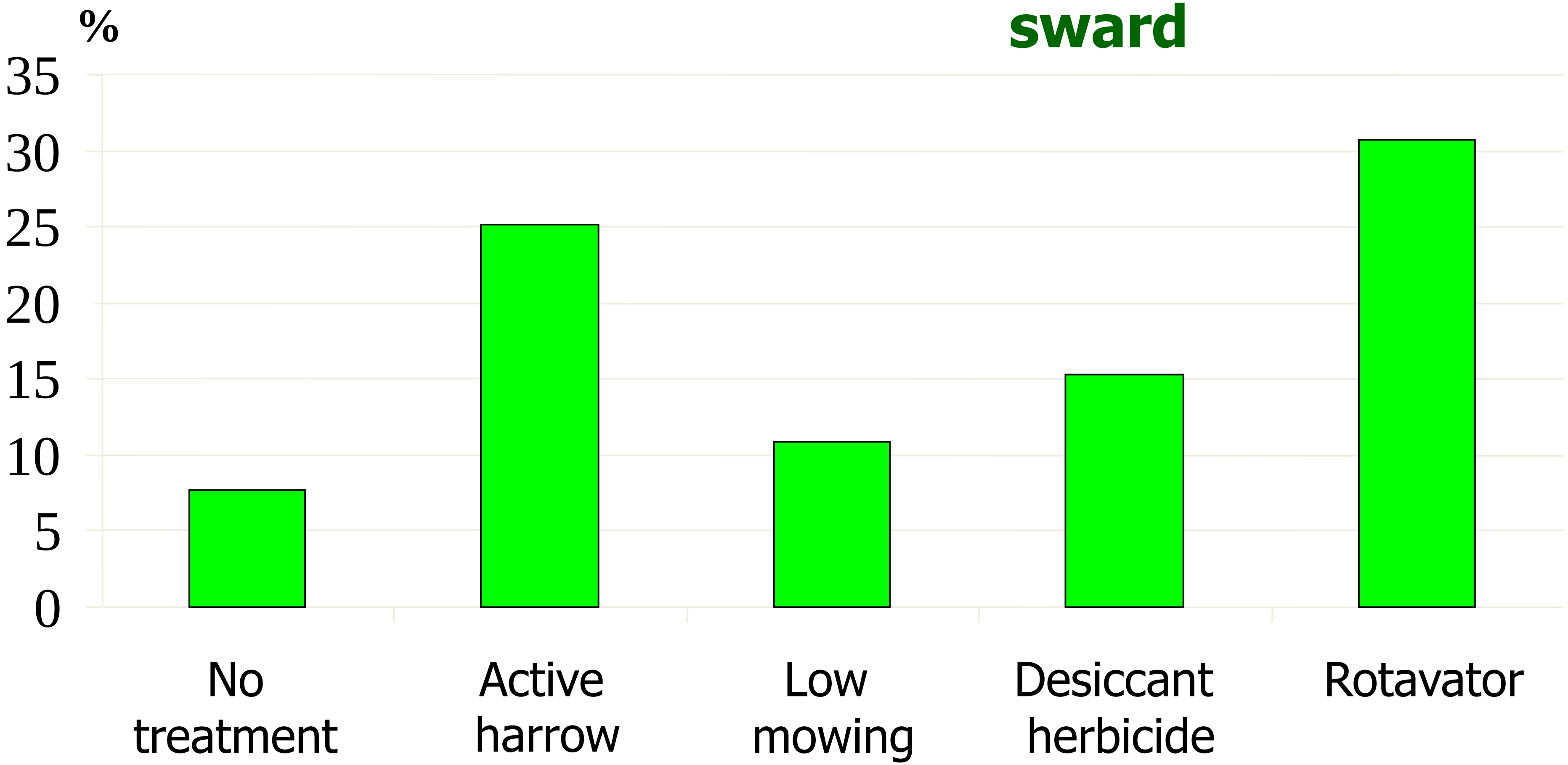
Photographs Piotr Goliński and companies materials

Complementary seeders equipped in the Guttler roller system

Photographs Piotr Goliński


Low mowing
desiccant herbicide
Preparation of sod for overdrilling
Photographs Piotr Goliński
Active harrow
Rotavator

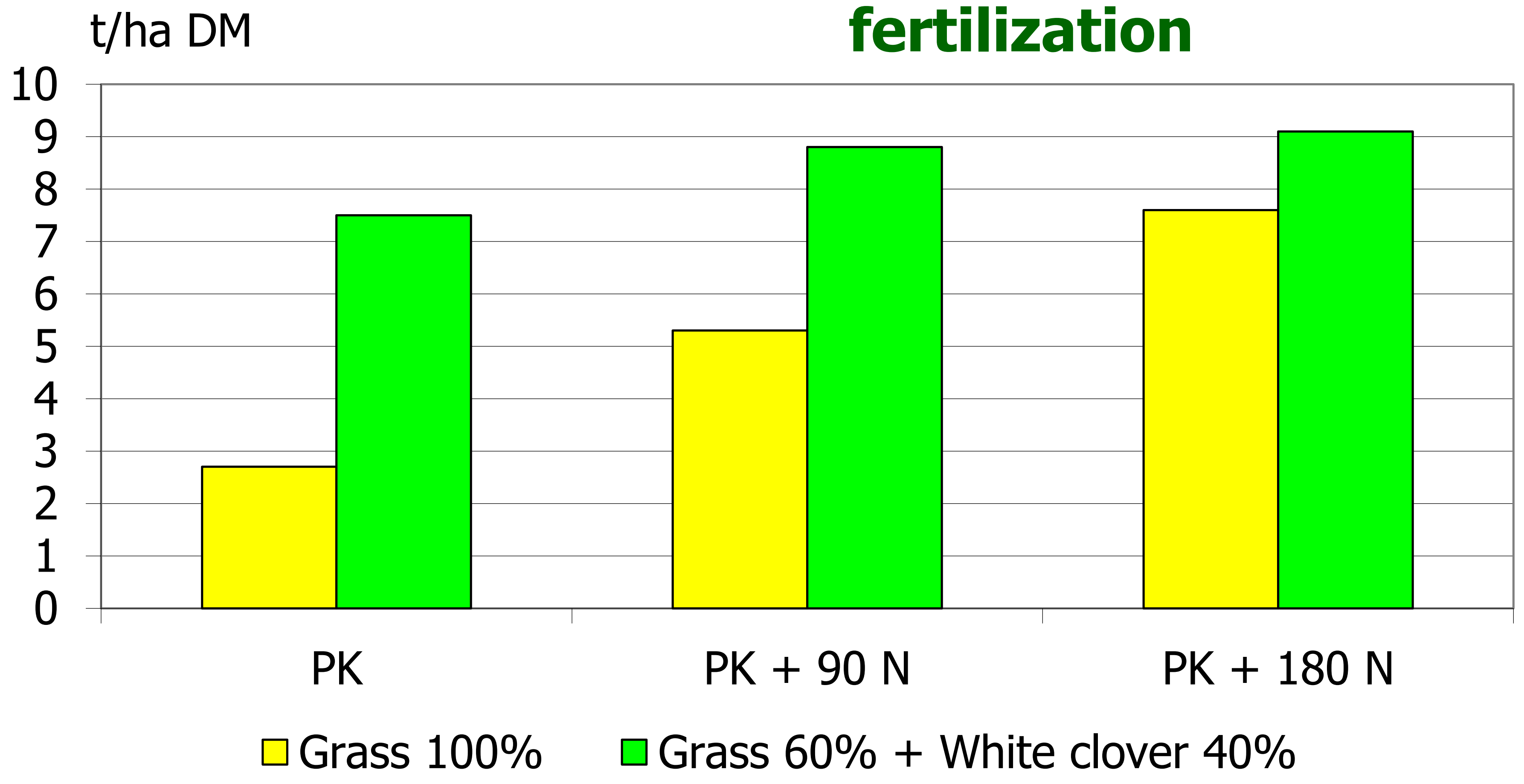
Impact of sod preparation methods before overdrilling on share of white clover in the sward



Goliński, 2001


Production in herbage from grassland more amounts of "native" protein
Grass-legume mixtures composed on the basis of functional features of the components
Photograph Piotr Goliński

Yield of meadow sward depending on the mixture composition and the level of fertilization



Mikołajczak, 1996

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Multi-species mixtures for pastures with the addition of meadow herbs

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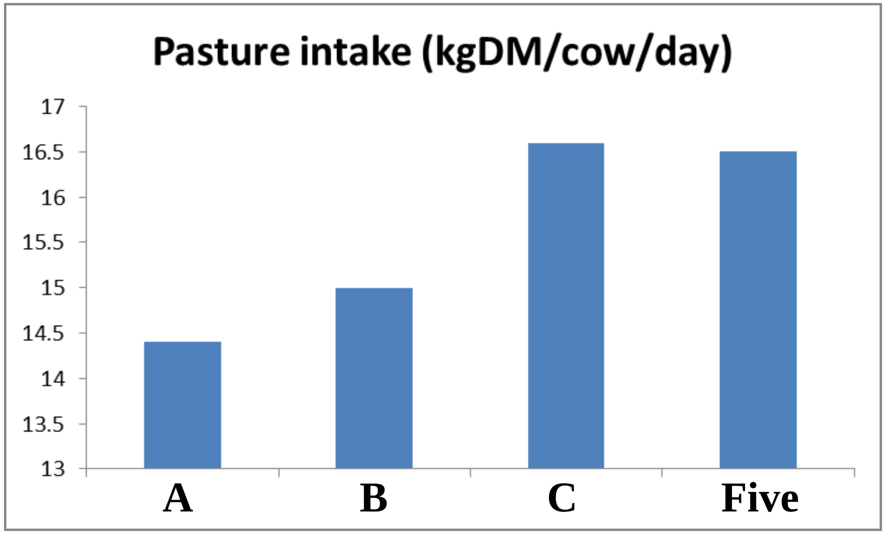
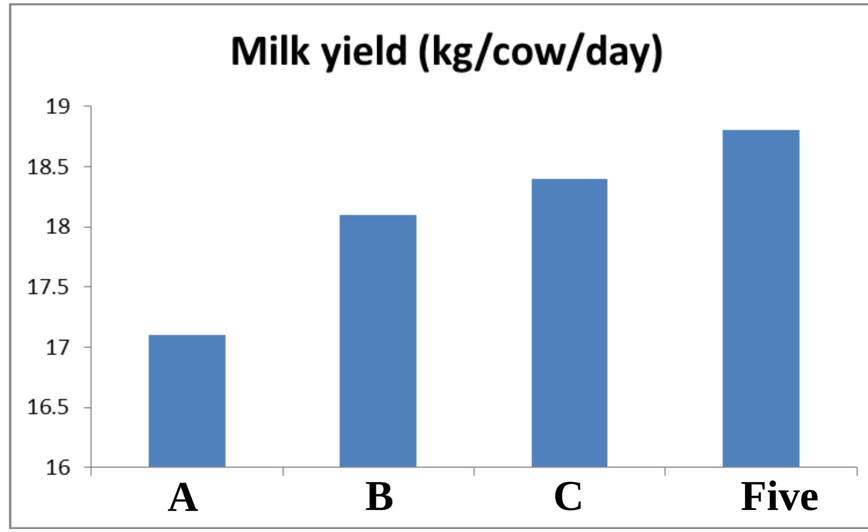
Influence of the species number in the mixture on feed intake and milk yield





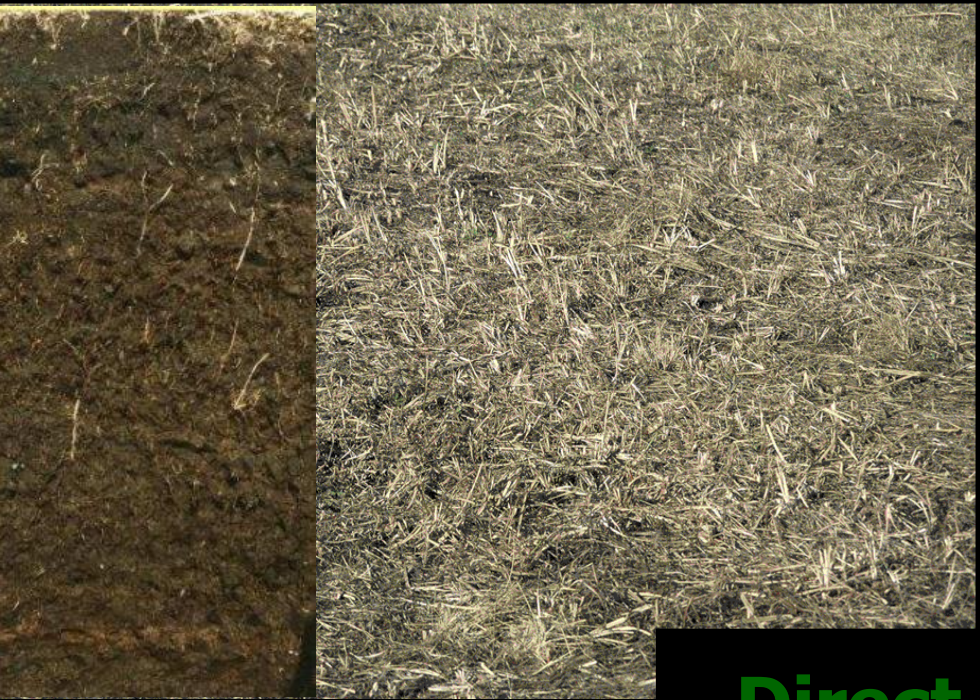
	Lp	Fa	Tr	Tp
A	1	0	0	0
B	2/3	0	1/6	1/6
C	1/2	1/6	1/6	1/6
Five	mixture of 5 species			

Grass-legume mixtures yield better in comparison to single-species sward with the same level of fertilization

Nitrogen fertilization=12 kg/t of expected DM yield

Collins et al., 2014

Direct drilling



Photographs Piotr Goliński

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Renovation of grasslands using a Horsch no-tillage seeder

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Photograph Piotr Goliński

Grassland fertilization

Principles of nitrogen grassland fertilization

- dose reduction on peat soils
- maximum level of fertilization – marginal yield of 1 kg nitrogen not less than 10 kg DM
- reduction in fertilization in the presence of legumes in the sward (1% of share means 3-5 kg/ha N less)
- dividing the nitrogen annual dose (max. 60-70 kg/ha per regrowth), the fertilization criterion is the presence of $N\text{-}NO_3$ below treshold 0.2% in DM

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Yield of grassland sward depending on type of nitrogen fertilizer (dt DM/ha)

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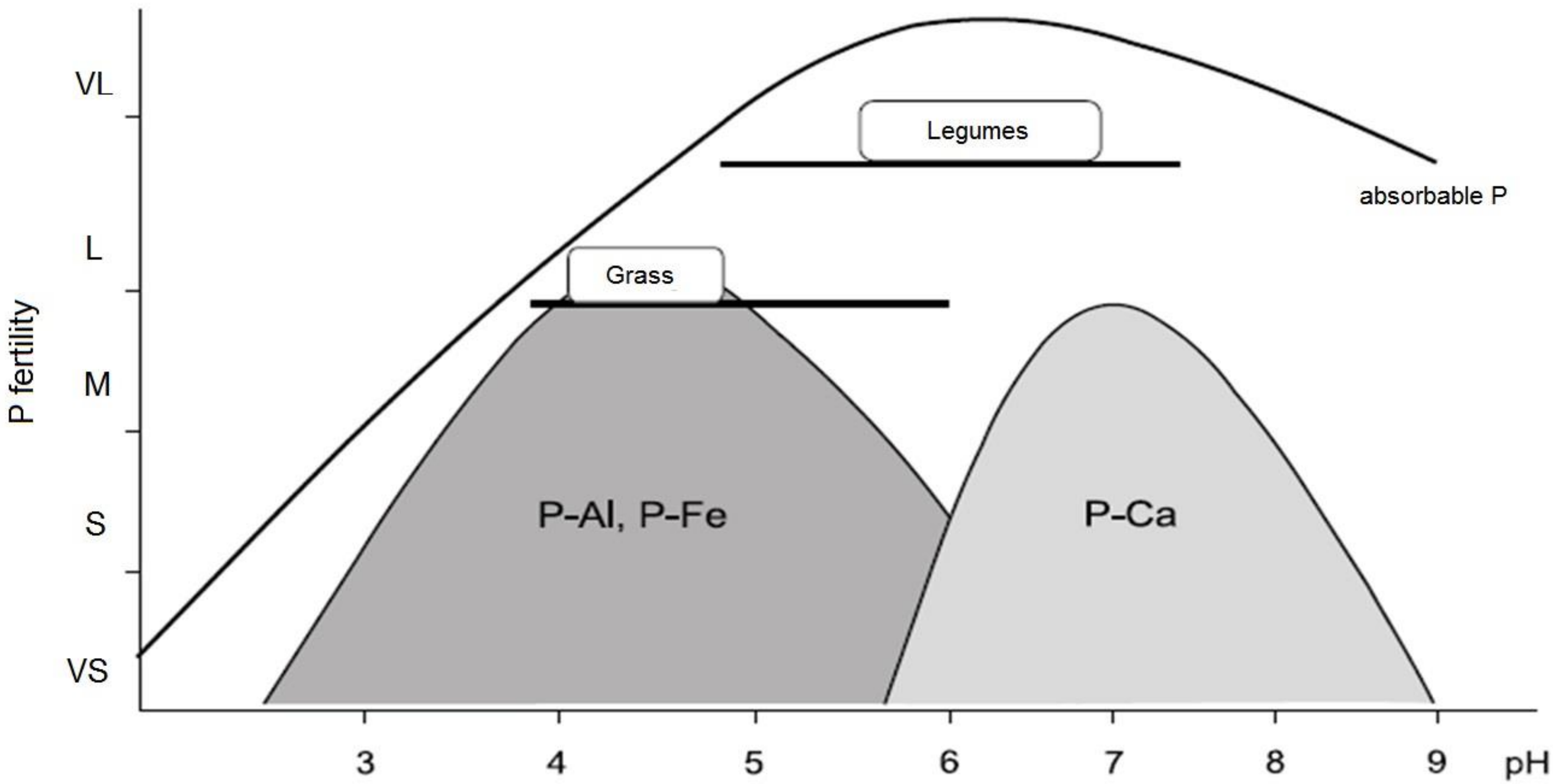
Level of nitrogen fertilization (kg/ha)	Slurry	CAN (N-28)
40	76,6	75,1
80	89,2	88,8
120	107,2	98,9
160	119,2	108,5

Ernst, 1998

Photographs Piotr Goliński

The binding force and absorption of inorganic phosphorus against the background of soil pH



Grzebisz, Goliński and Potarzycki, 2014

P-Fe, P-Al, P-Ca - phosphorus associated with iron, aluminum and calcium

Fertility: VS - very small, S - small, M - medium, L - large, VL - very large

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Principles of potassium grassland fertilization

- increasing the dose on peat soils
- increasing fertilization in the presence of legumes in the sward
- dividing the dose of potassium (max. 50 kg/ha per regrowth), the fertilization criterion is the presence of K at the optimal level of 1.7% in DM
- include the luxury absorption of potassium of 90-100%
- limitation of the rate on pastures by 20 kg/ha per year and per LU due to excrements

Water management on grassland

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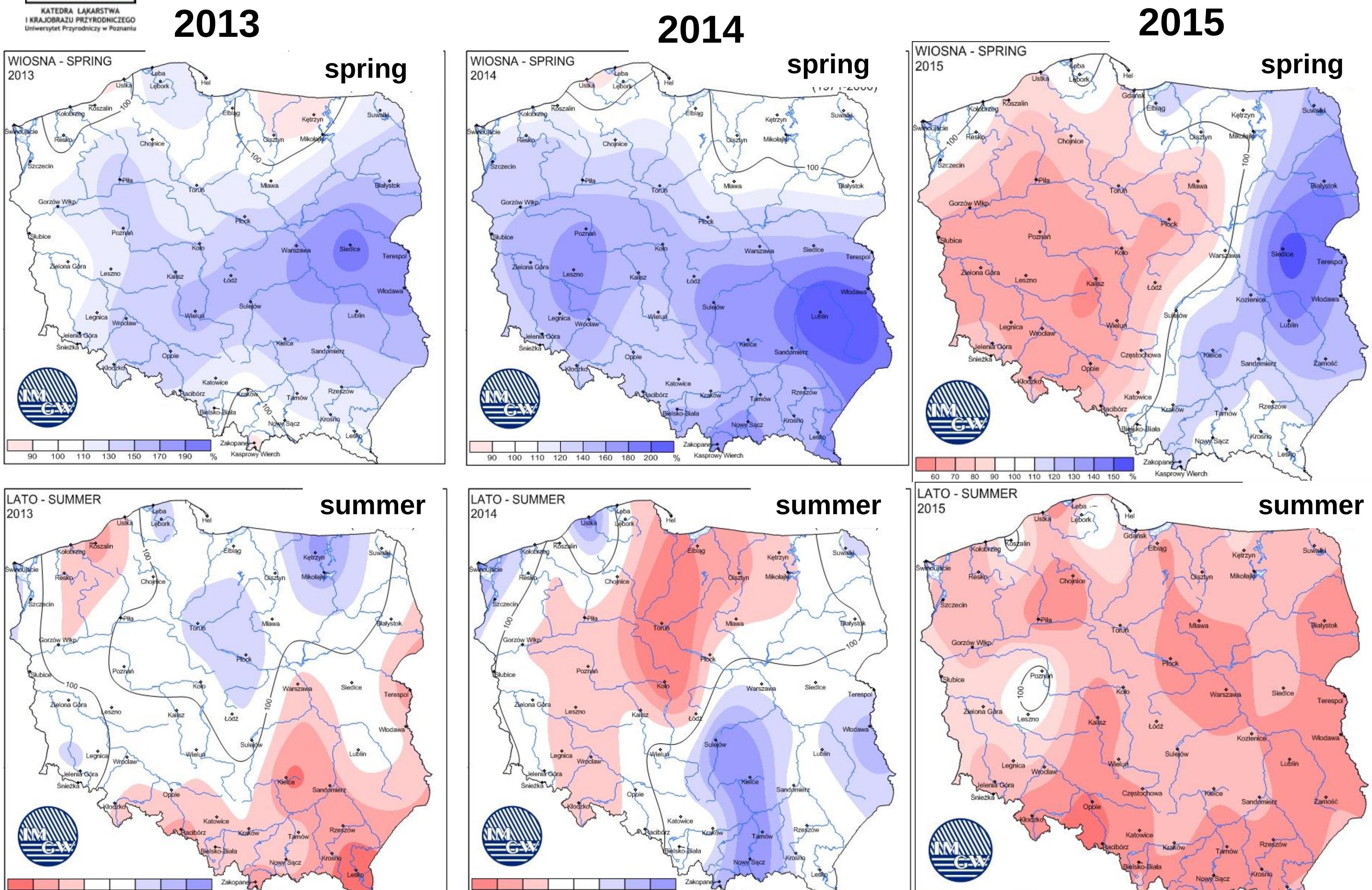
Anomalies of the total rainfall in spring and summer in 2013-2015 compared to the years 1971-2000

Inno4Grass



Own elaboration based on IMGW, 2018

Anomalies of the total rainfall in spring and summer in 2016-2018 compared to the years 1971-2000

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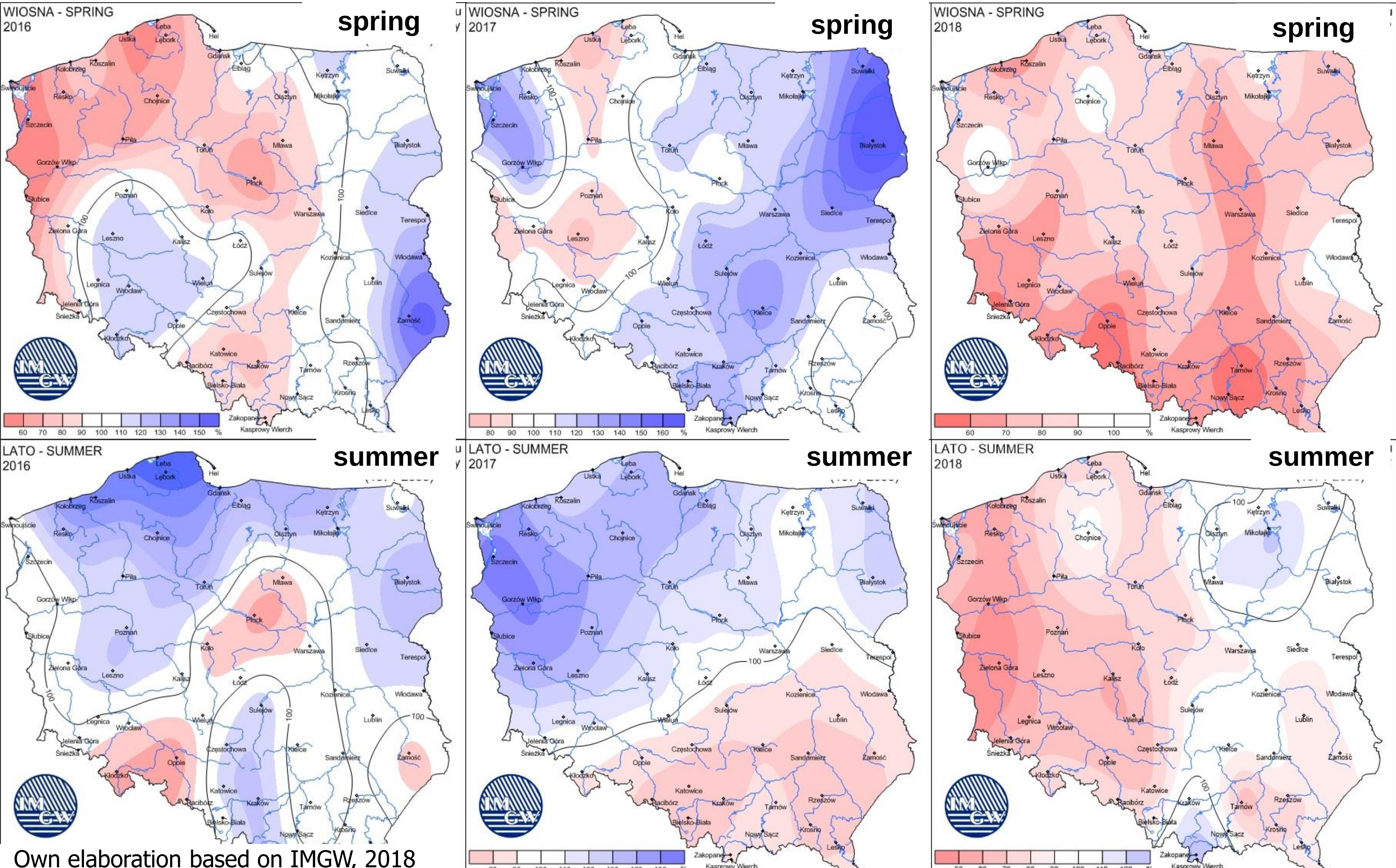
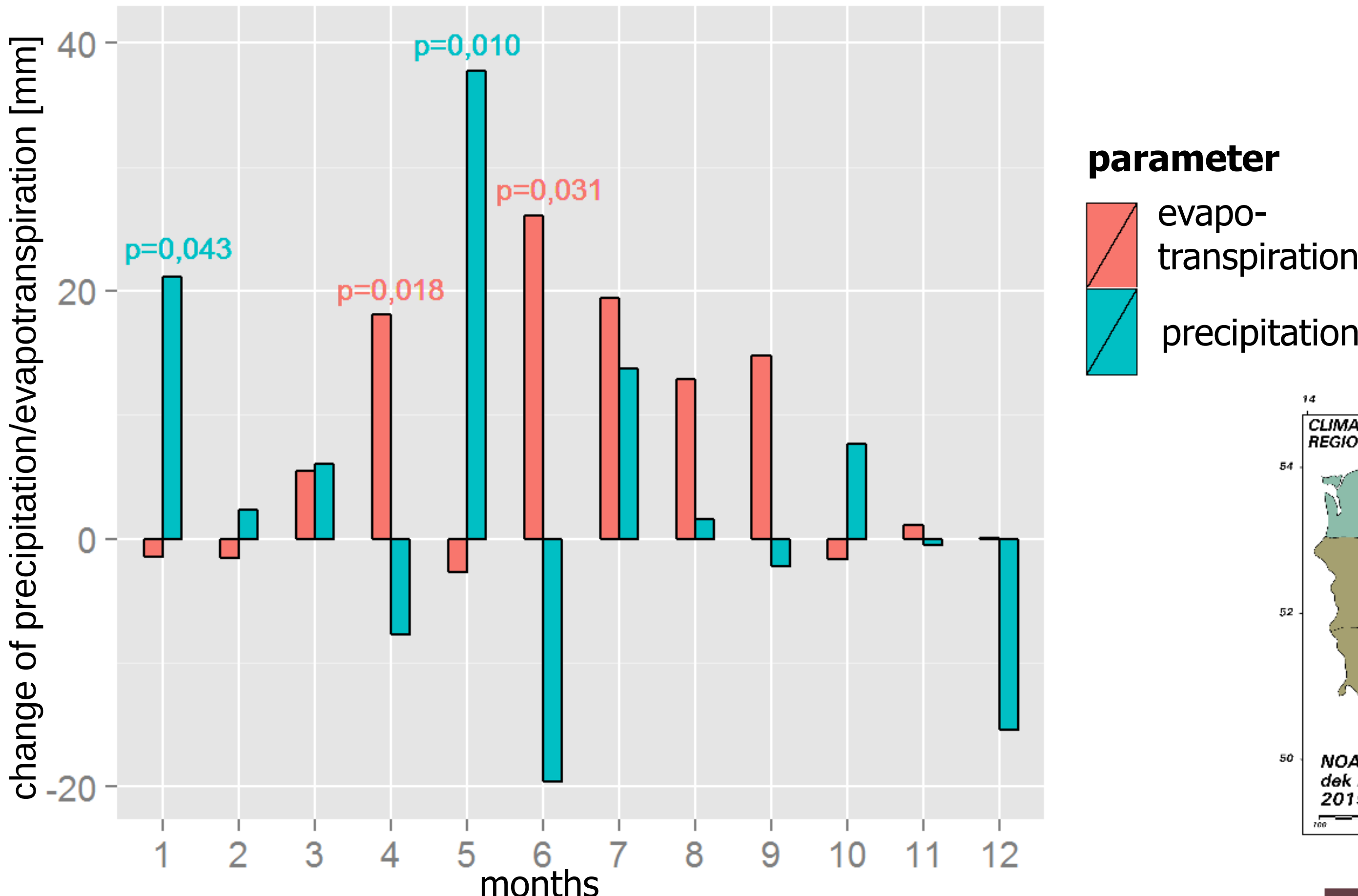
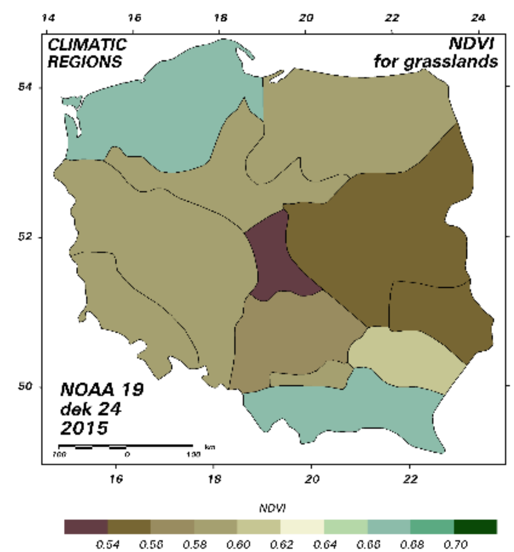
2016 2017 2018



Own elaboration based on IMGW, 2018

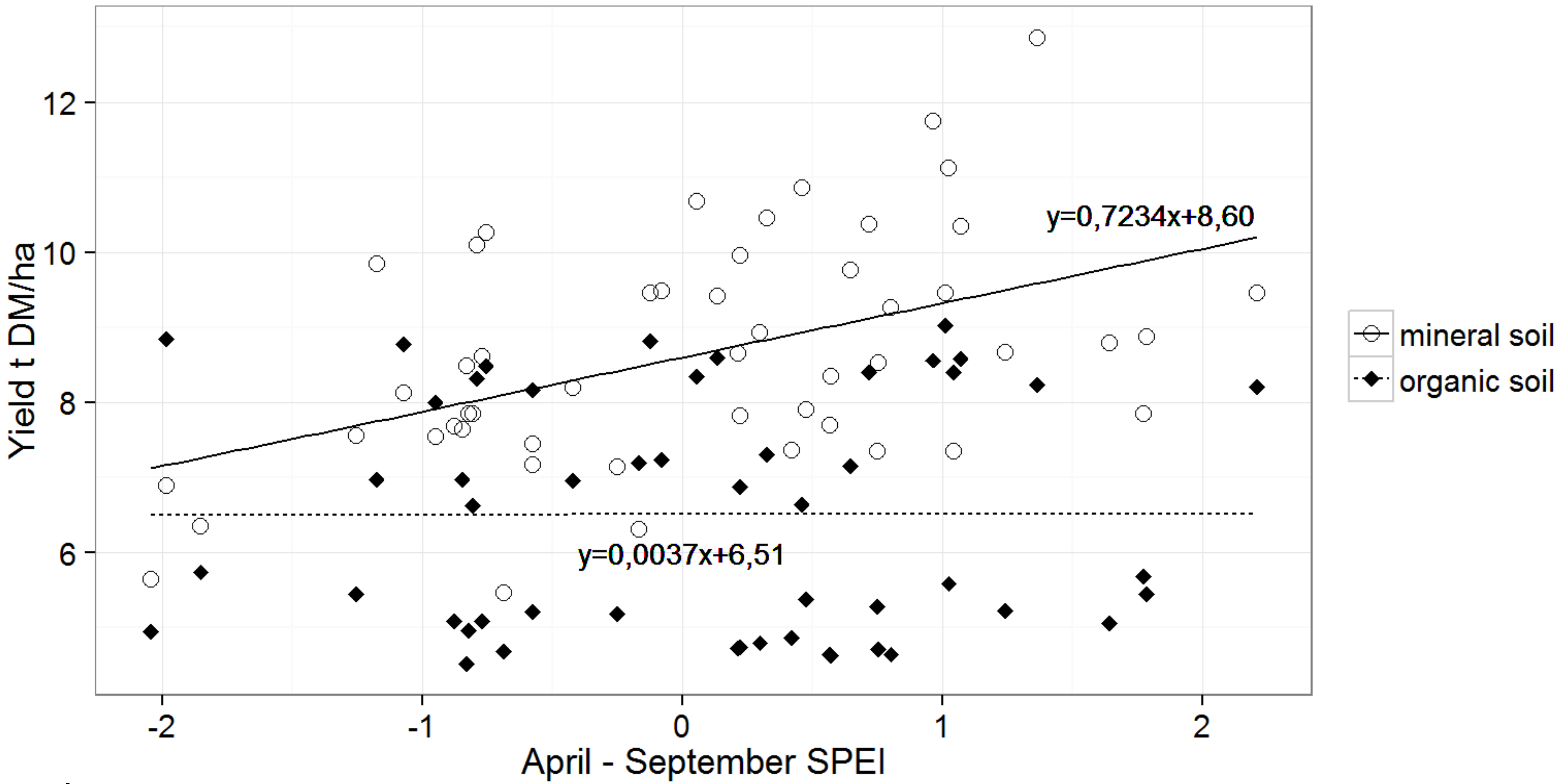
Changes in the precipitation and evapotranspiration in particular months in Wielkopolska in the years 1985-2014





Goliński et al., 2015

Relationship of annual sward yield of grasslands and standardized precipitation evapotranspiration index (SPEI) for the 6-month period in 1965-2014 in Experimental Station Brody (Wielkopolska province)



Goliński et al., 2015

Irrigation of pastures in Poland - ensures continuity of feed supply during the growing season

Photographs Piotr Goliński

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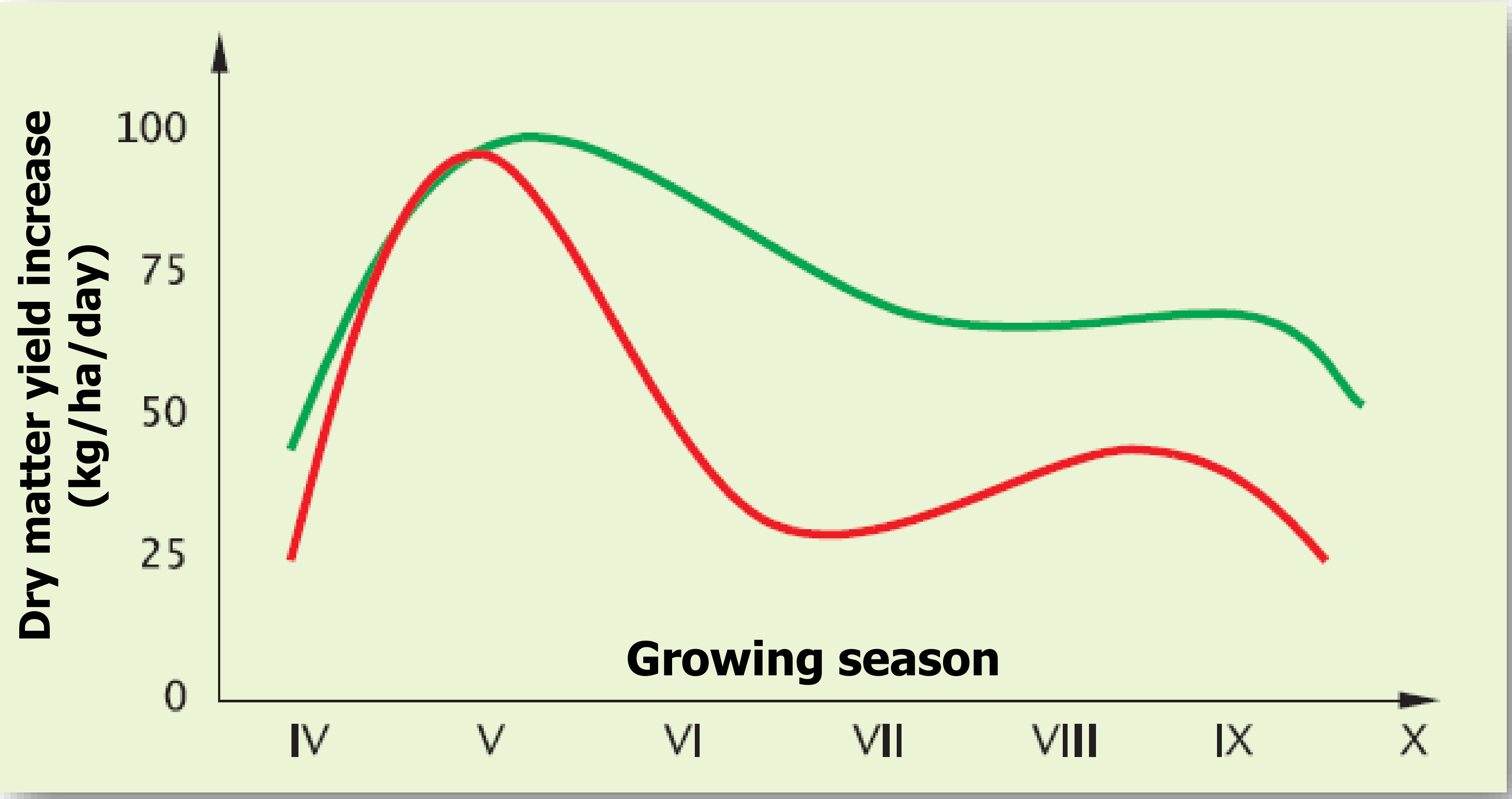
The increase of dry matter yield on irrigated and non-irrigated ryegrass pastures in the central part of Poland



Activities for the effective production of fodder from grassland in regard to climate changes

- rational irrigation of grasslands on mineral soils
- renovation of grasslands with the use of the best seed mixtures and new grass varieties resistant to thermal and moisture stress
- limiting the effects of drought (application of manure fertilization, good potash nutrition, appropriate sward management treatments, weed control)
- use of remote sensing through systematic monitoring of the status of grassland vegetation, which enables more accurate selection and dosing of fertilizers or more precise and efficient irrigation

Grazing management

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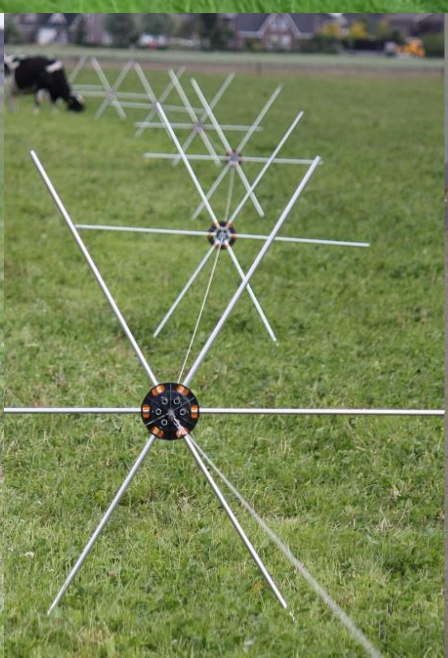
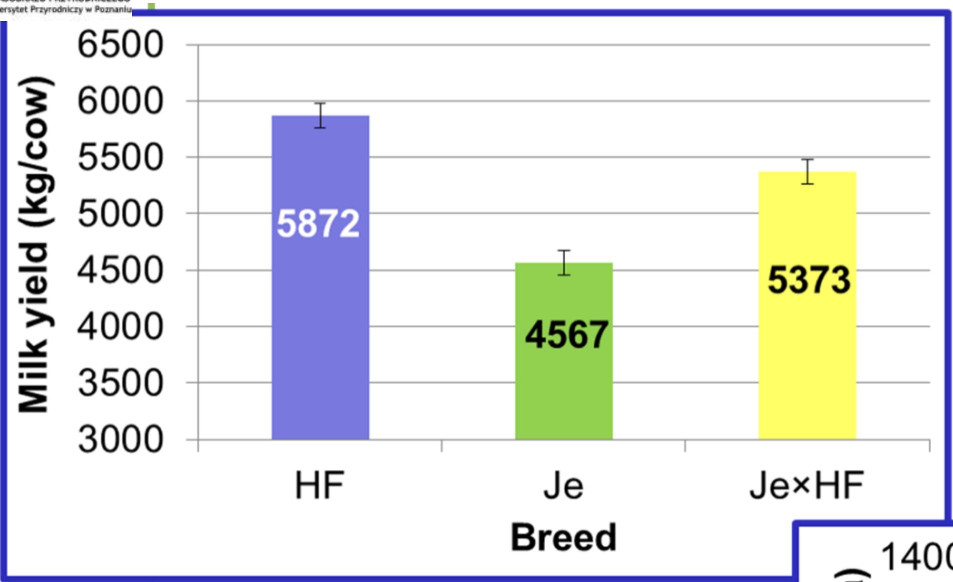
Innovations in sward yield estimation and pasture grazing management



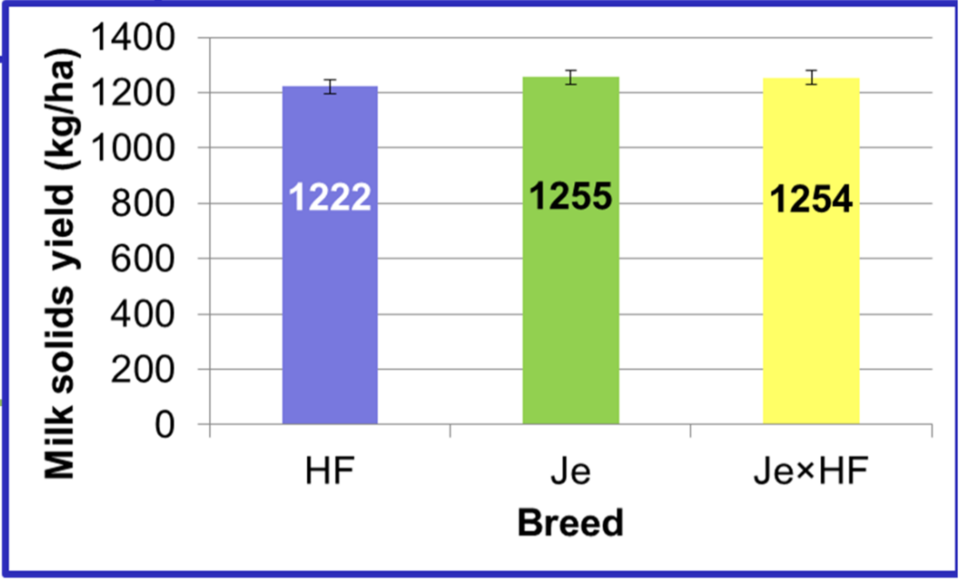
Photographs Piotr Goliński

The impact of cattle breed on production results in grazing feeding system



Significant improvement in calving and health indicators of cross-breeding cattle - better economic effect of milk production

Breed	
HF	**Holstein-Fries.**
Je	**Jersey**
Je×HF	**crossbreed**



MultiSward
http://www.multisward.eu

Dillon et al., 2014

Grazing of dairy cows on the pasture in Poland

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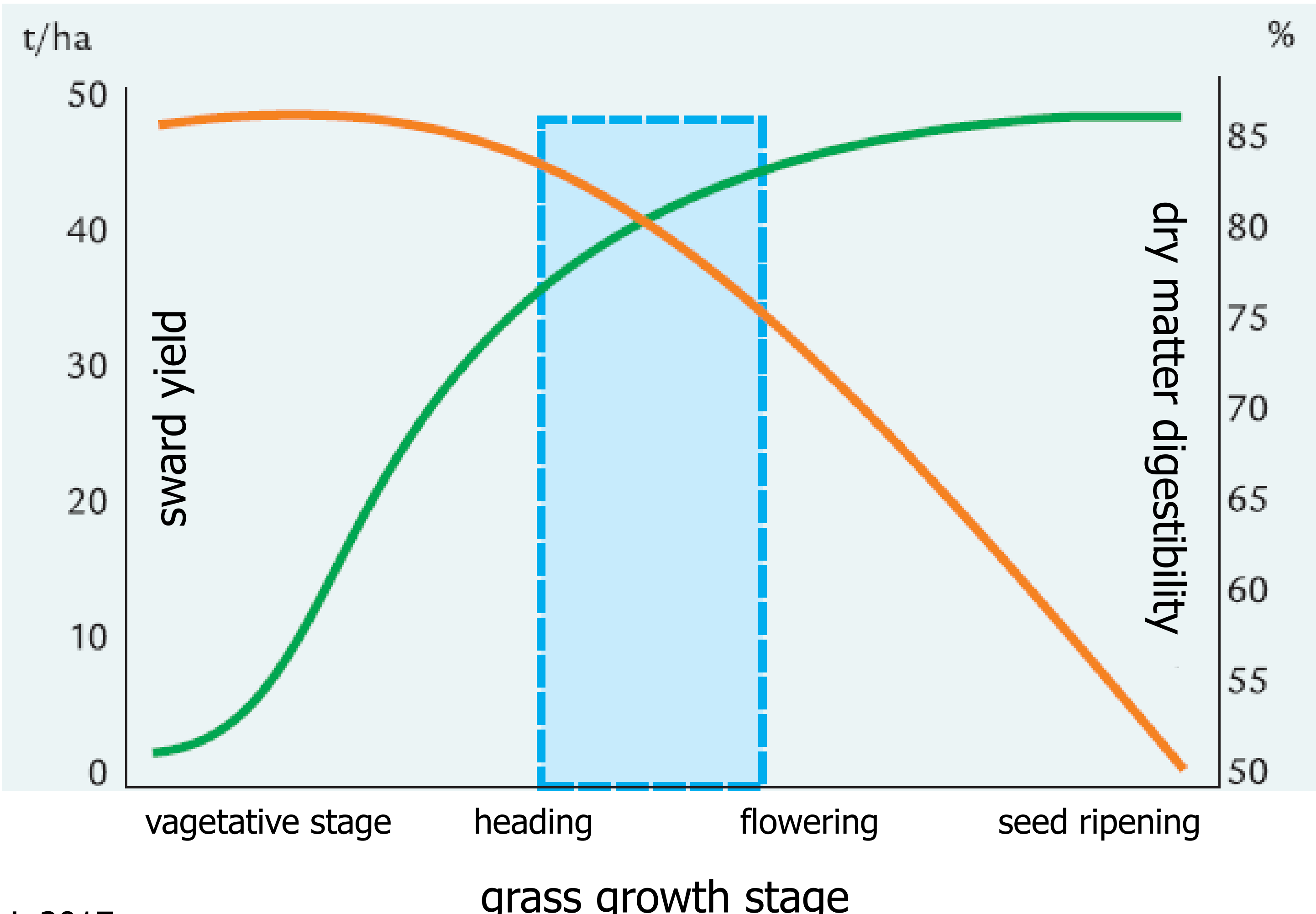
Inno4Grass

Photograph Piotr Goliński

Cutting and conservation of grassland sward

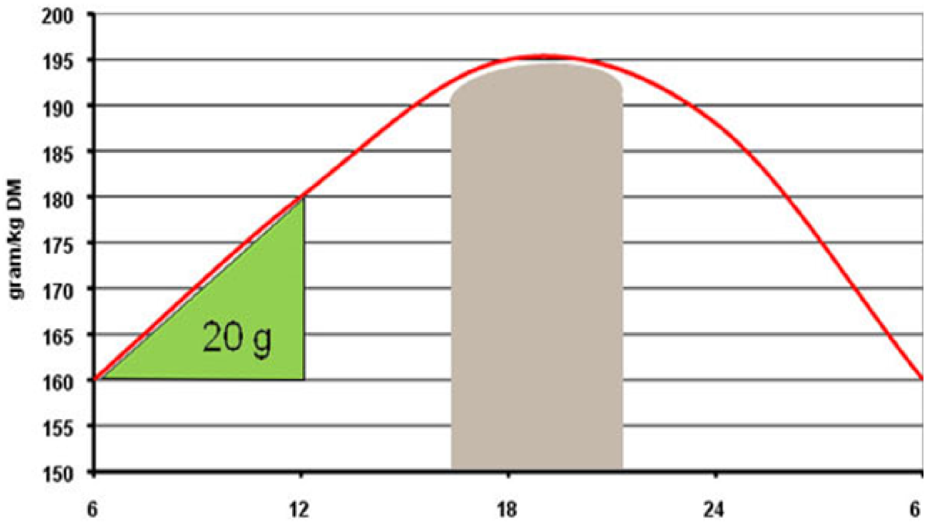
Optimal stage of meadow sward mowing



Goliński, 2017

Optimal time for meadow sward mowing during the day

Mowing the sward in the afternoon and evening



Lely, 2015

6 hours later = ***+20 g of sugars/kg DM***

in 1000 kg DM

+20 kg of sugars more → +160 kg of concentrate feed

Effect of sward mowing term of first regrowth on quality of fodder and effectiveness of milk production

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Specification	Sward mowing term of the first regrowth		
	heading	begin stage of flowering	full stage of flowering
NEL energy content (MJ/kg DM)	**6.4**	**6.0**	**5.8**
NEL energy yield (MJ/ha)	**22400**	**24000**	**26560**
Daily intake of a basic feed per cow (kg DM)	**13**	**12**	**11**
Daily milk yield from the basic feed per cow (kg)	**14.3**	**11.3**	**8.5**
Milk production from the basic feed (kg/210 days)	**3003**	**2373**	**1785**
Consumption of concentrates in the year (dt/cow)	**8**	**11**	**15**

Rieder, 1996

Photographs Piotr Goliński

Technical innovations in the harvesting and conservation of grassland sward

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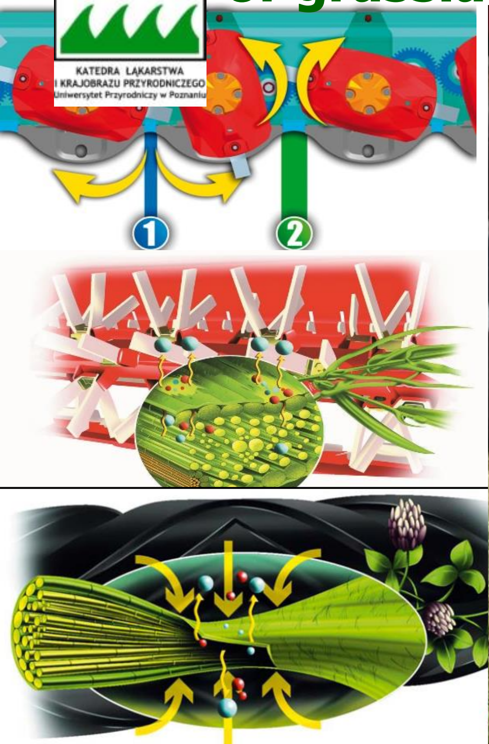


Photographs Piotr Goliński and companies materials

Photographs Piotr Goliński

Hay production based on drying in special barn

Factors determining the silage quality

A. Susceptibility of sward to ensiling

- sugar content
- buffer capacity
- dry matter content (degree of sward wilting)
- soil contamination
- occurrence in sward of lactic acid bacteria

B. Ensiling technique

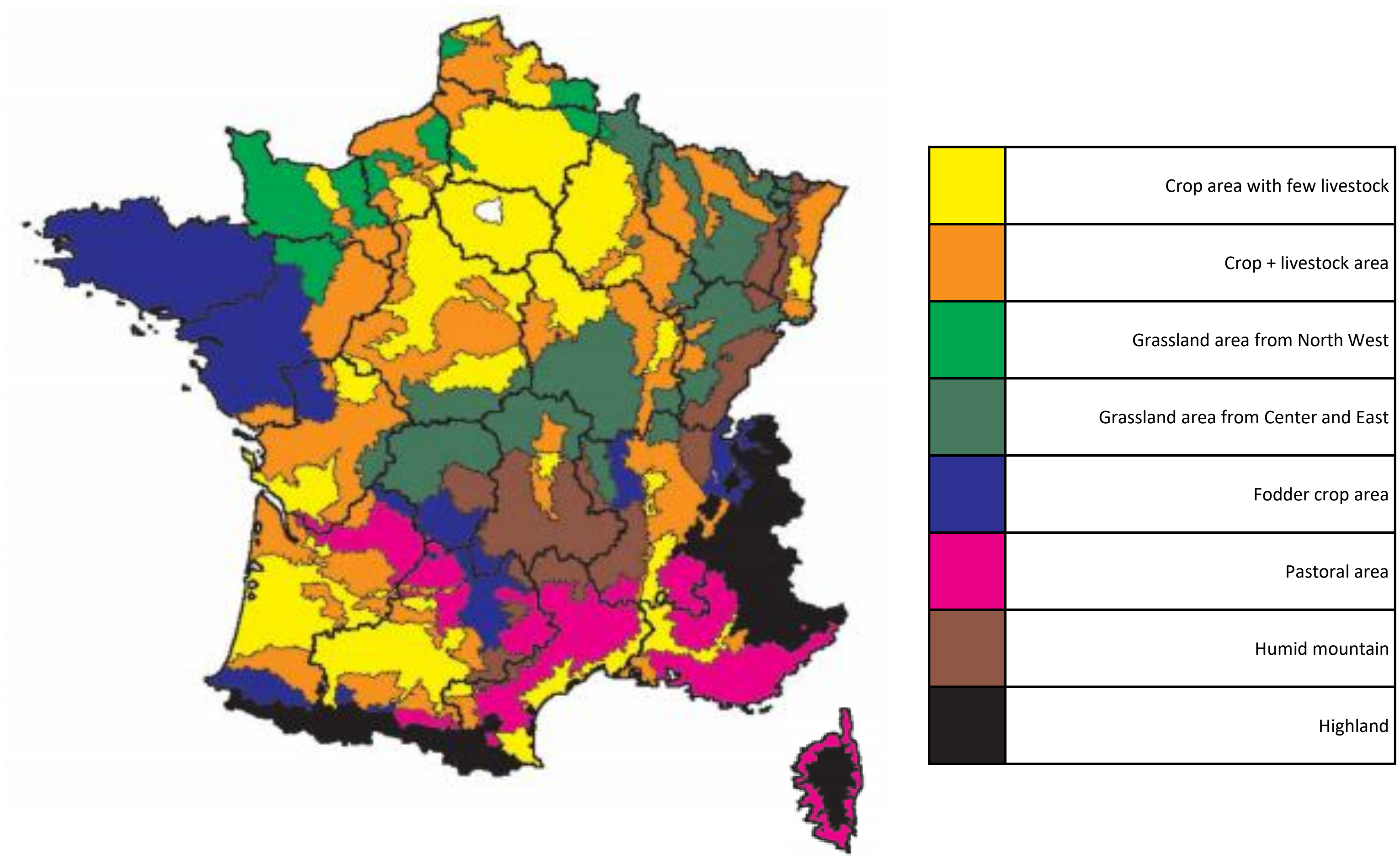
- fragmentation of the sward
- compaction and density of sward
- time of filling a prism or silo
- silage additives
- quality of foil used for covering or wrapping

France

Main livestock areas in France

Main herbivores system:

- Dairy & beef cattle
- Dairy & meat sheep
- Dairy goat
- Horses



Source: SCEES

Key numbers on cows of France

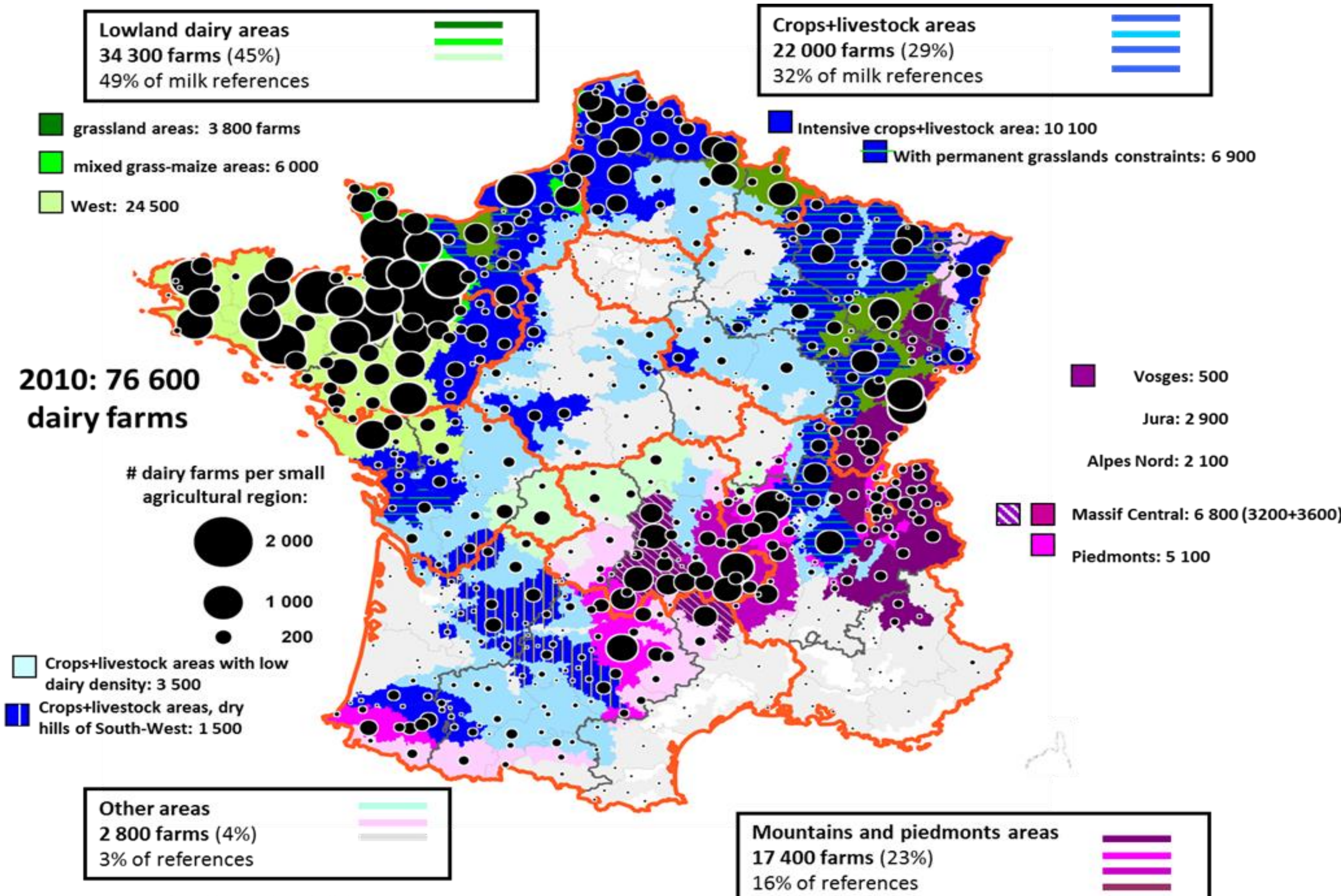
Criterion	Before quota milk	2017	Main breeds	Secondary breeds
Dairy	7.2 million cows	3.8 million	Prim'Holstein	Montbeliard, Normand
Beef	2.9 million cows	4 million	Charolais, Limousin	Blond d'Aquitaine, Salers, Aubrac

Milk volume : 25 billion of litres
20 % variation between highest and lowest month delivery
In 2019, expect 1 billion organic milk

Suckler cows: 48% are hold (~2 million) by 21 % beef farmers who have more than 70 cows/herd)
Main production weanlings sold on store market (64%)

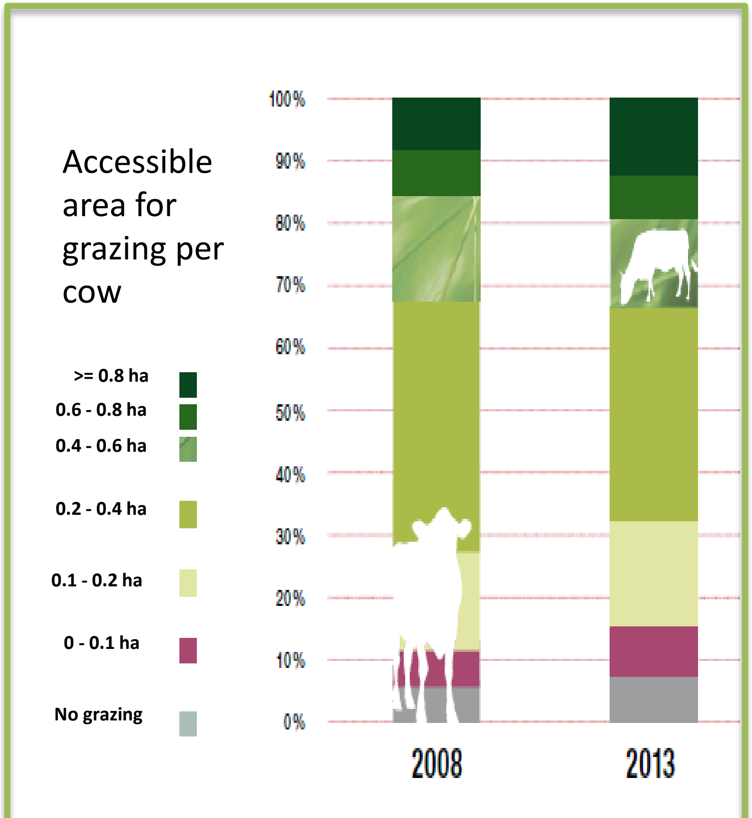
Source: GEB – Institut de l'Elevage, 2018

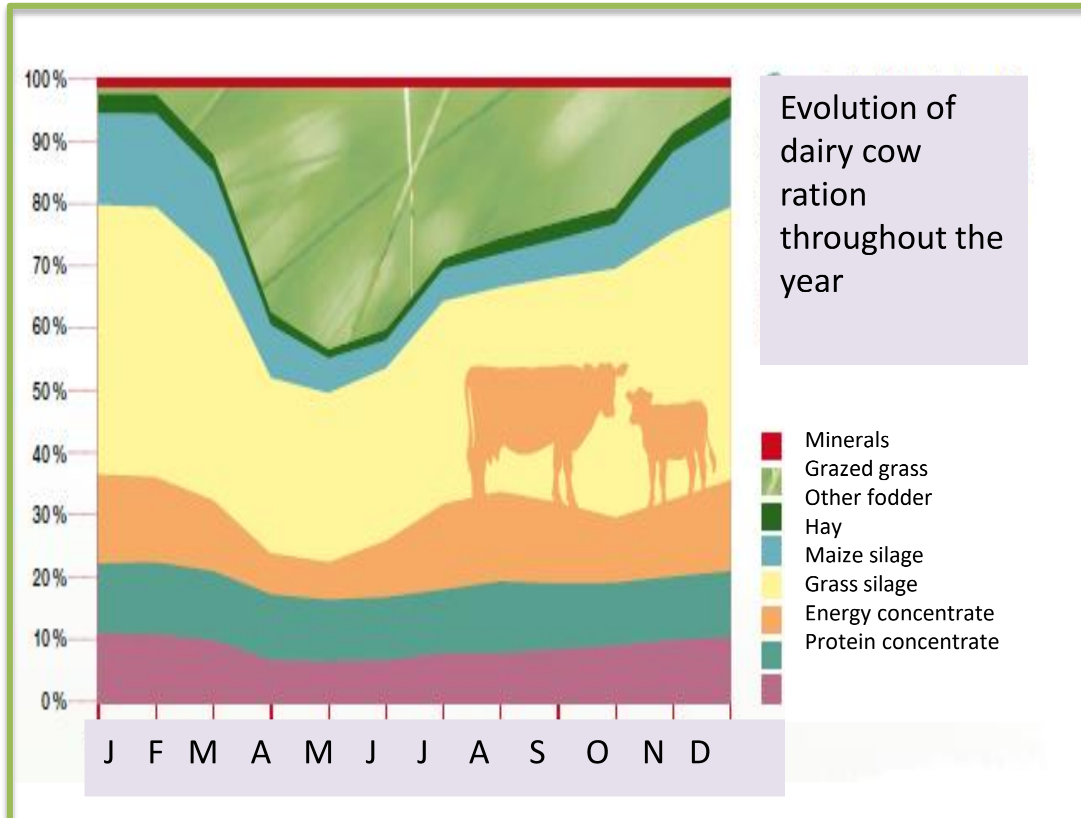
Classification of French dairy system from cows



Source: Agreste agricultural census, 2010 – Analyzed by Institut de l'Elevage

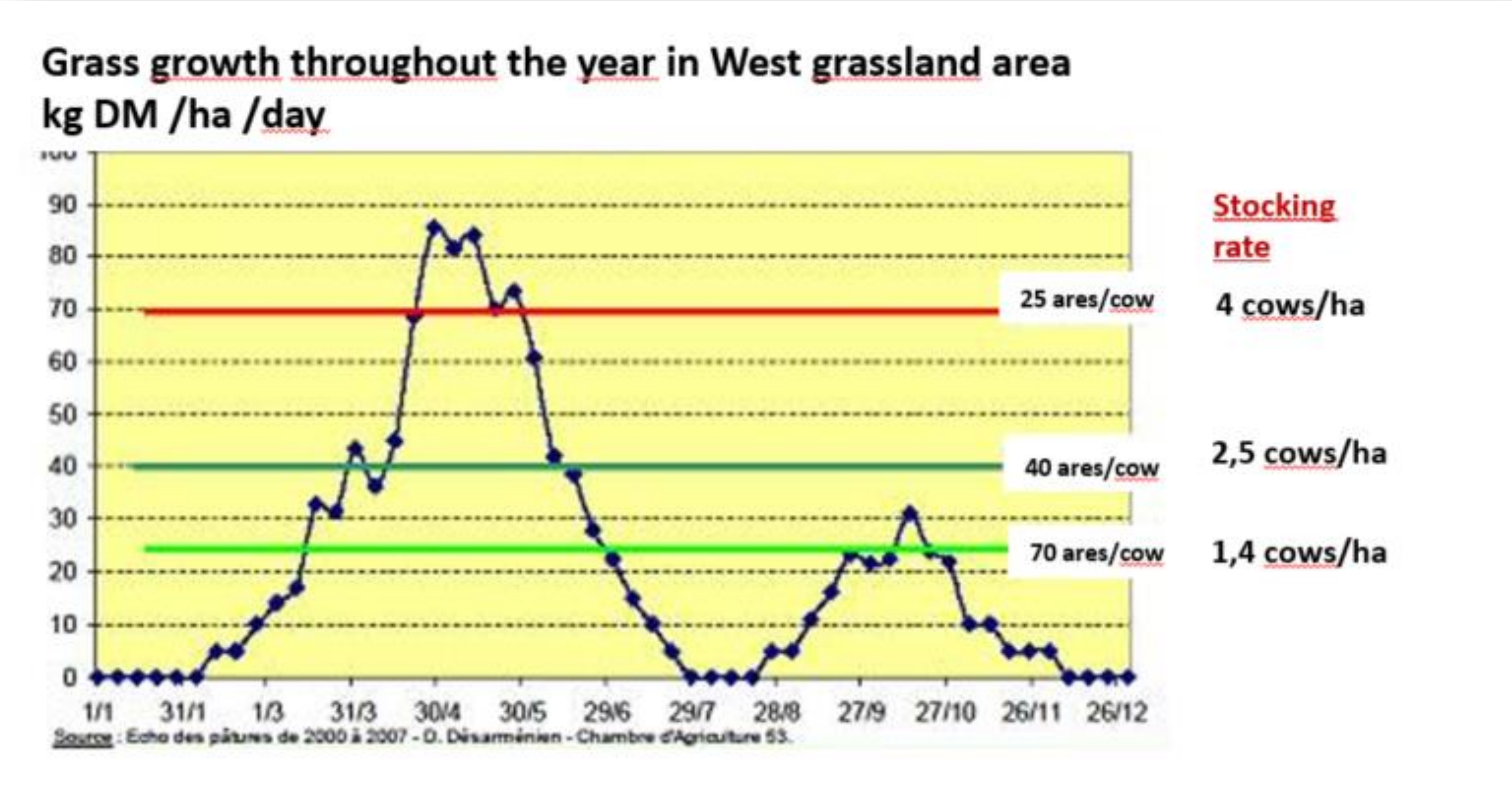
Grazing in relation to the ration



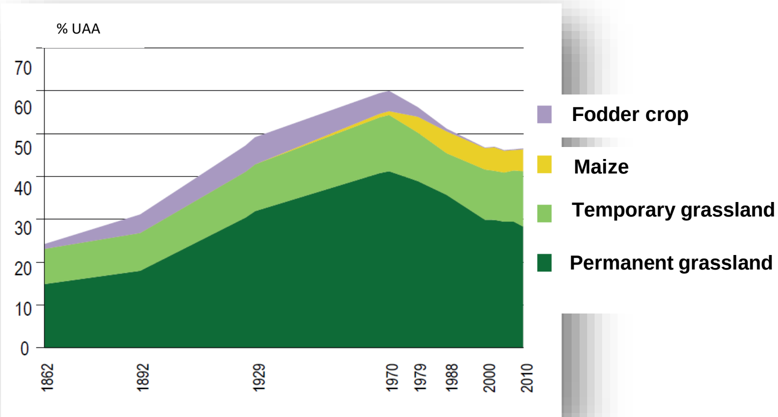


Source: Observatoire des élevages laitiers

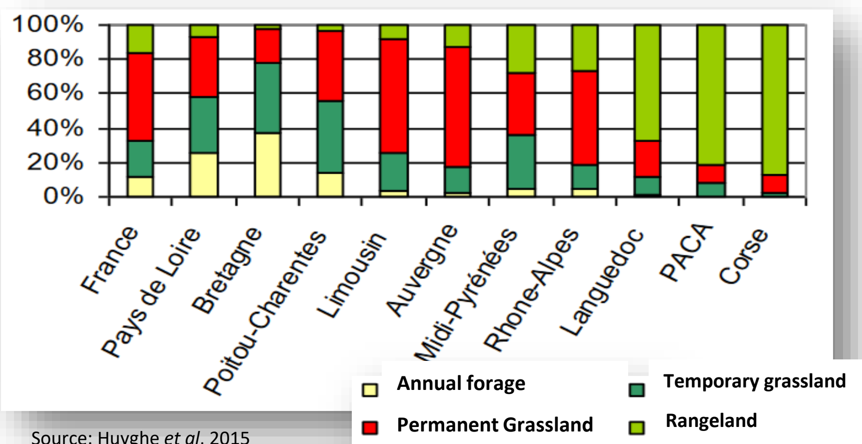
Cross between stocking rate and available grazing area will give proportion of grazed grass in ration



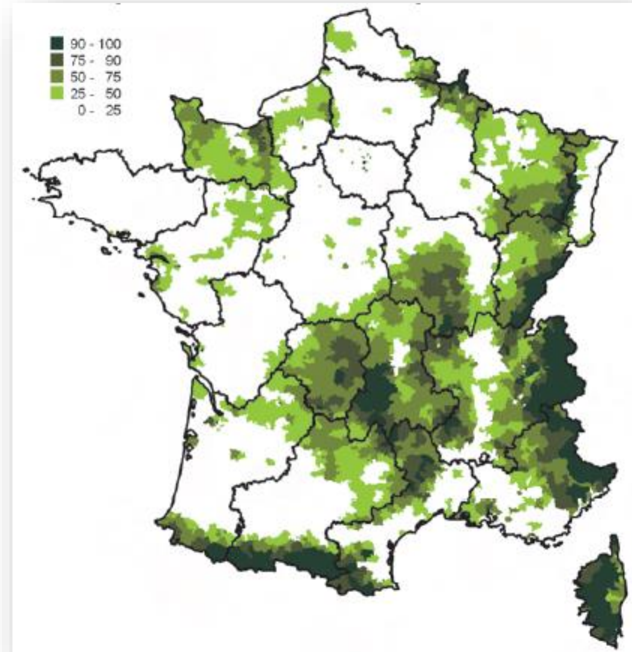
Composition & evolution of French forage area



Source: RGA 2010



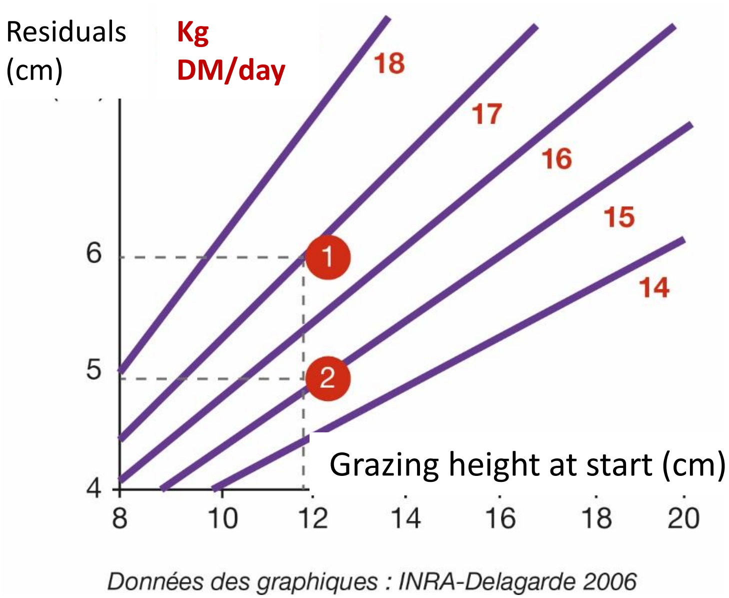
Source: Huyghe *et al*, 2015



% permanent grassland in FA

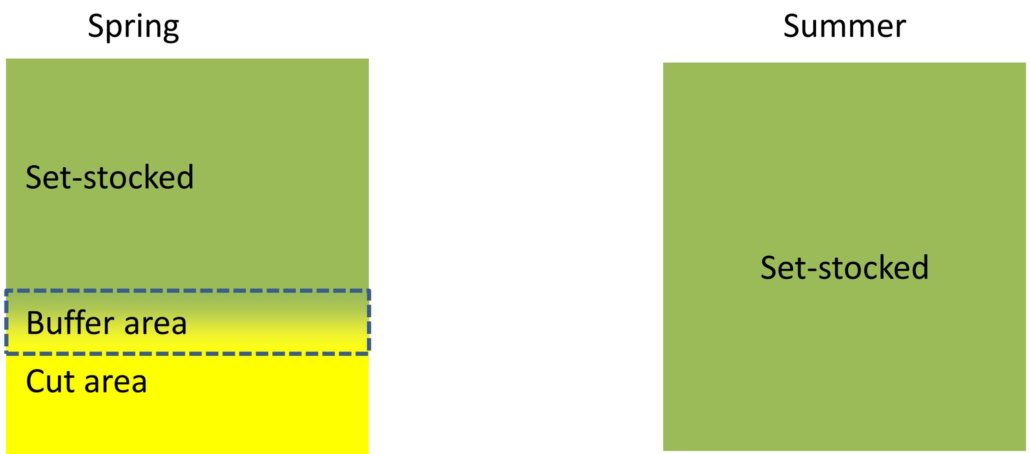
Source: RGA 2010

Dry matter intake per cow in fresh grass



- Choose your objective (entrance at 12cm)
  - More milk/cow:
    - Ingestion 17 kgDM/day => residuals 6 cm
    - Grass utilisation 1 600 kgDM/ha
  - More milk/ha
    - Ingestion 15 kgDM/day => residuals 5 cm
    - Grass utilisation 2 400 kgDM/ha

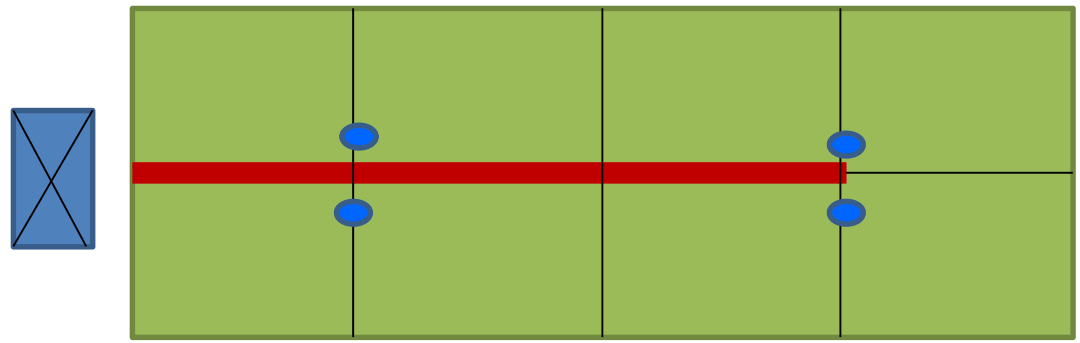
Grazing : set-stocking



Set stocking		Cow		Goat		Sheep		Horse	
Criterion	unit	min	max	min	max	min	max	min	max
Areas	are/LU	30	80	30	60	70	90	50	90
Entrance	Compressed height (cm)	7	8	6	8	6	8	5	7
Number of paddocks		1	3	2	3	1	3	1	3

(Hoden *et al.*, 1986 ; Doligez *et al.*, 2014 ; Lefrileux *et al.*, 2012 ; Leray *et al, 2016 ;* Pottier *et al.* 2009)

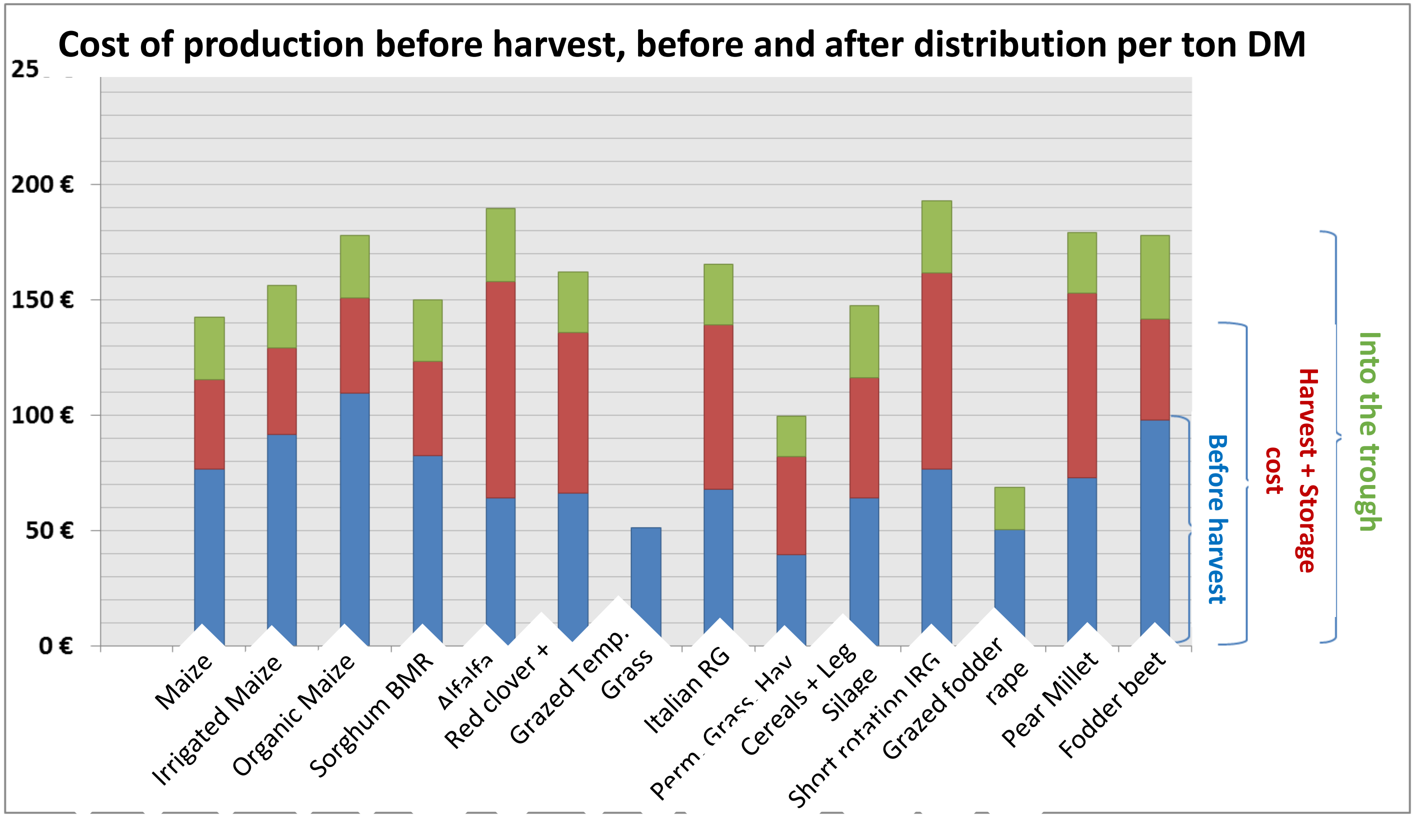
Grazing : rotational grazing



Rotational grazing		Cow		Goat		Sheep		Horse	
Criterion	unit	min	max	min	max	min	max	min	max
Areas	are/LU	25	60	25	40	nc	nc	30	80
Grazing	days / paddock	3	5	2	4	3	7	3	7
Rest	days	20	40	15	45	nc	nc	20	40
Entance	Compressed height (cm)	8	15	12	14	10	15	5	10
Residuals	Compressed height (cm)	3	6	6	8	4	6	3	7
Number of paddock		5	15	4	8	6	10	3	7

Sources : Institut de l'Elevage *et al.,* 2016 ; Doligez *et al.*, 2014 ; Leray *et al., 2016 ;* Lefrileux *et al.*, 2012 ; Pottier *et al.*, 2009 ; Prairiales, 2005).

Cost of production before harvest, before and after distribution per ton DM



Source: PEREL, 2013

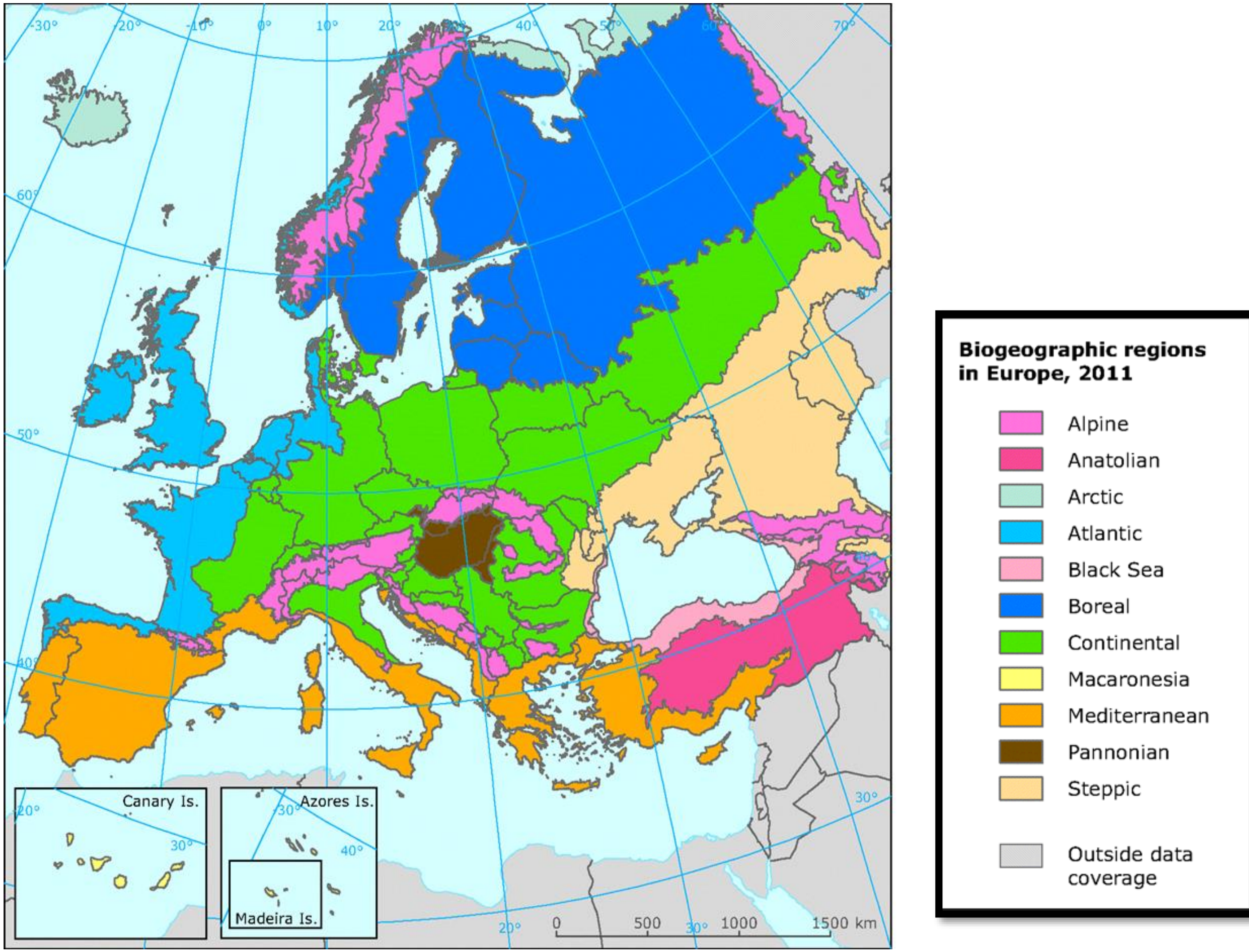
Italy

Grasslands in Italy

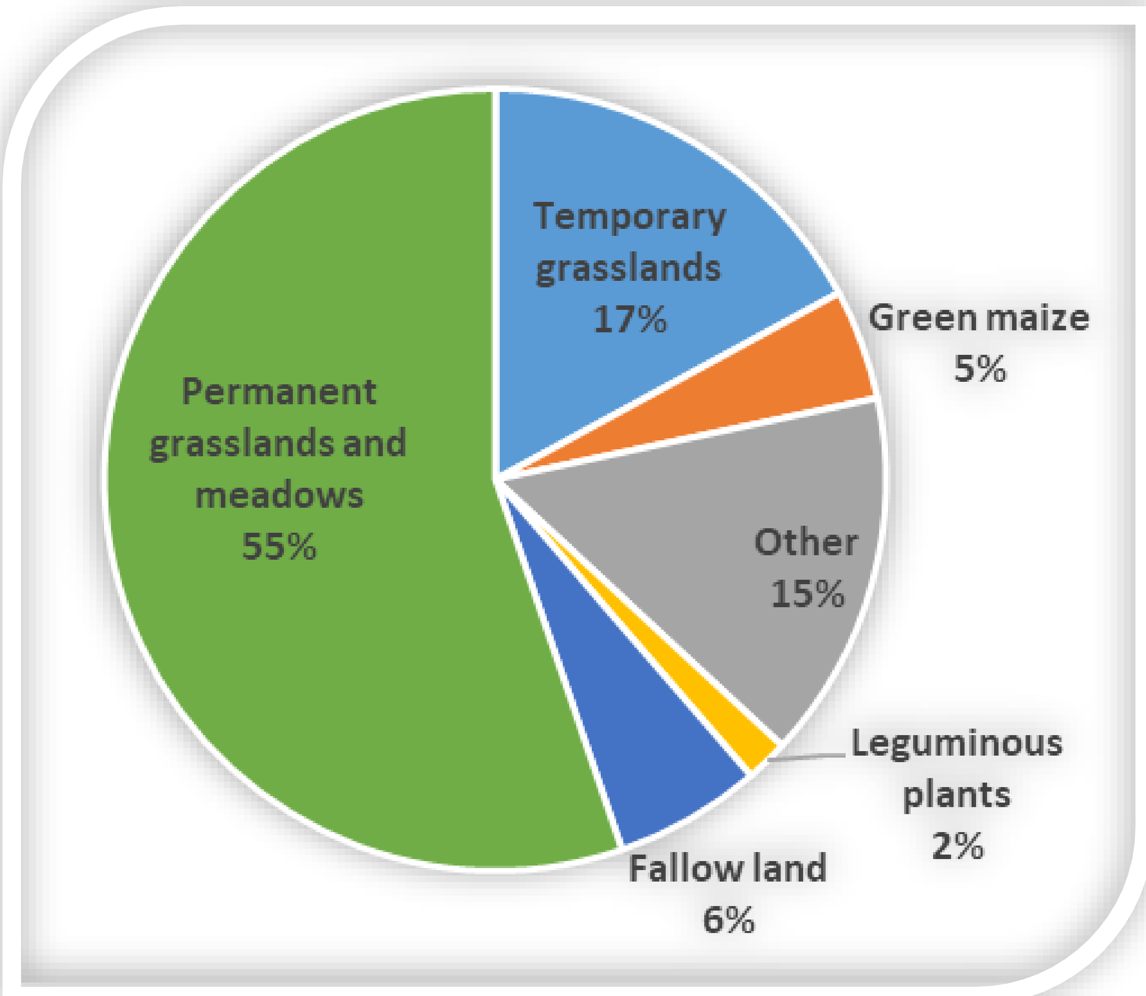
Claudio Porqueddu[1], Rita Melis[1], Lorenzo Pascarella[2] e Giovanni Peratoner[3]

[1] CNR-ISPAAM, Sassari - [2] AIA, Roma – [3] LAIMBURG, Bolzano

Climatic areas in Italy



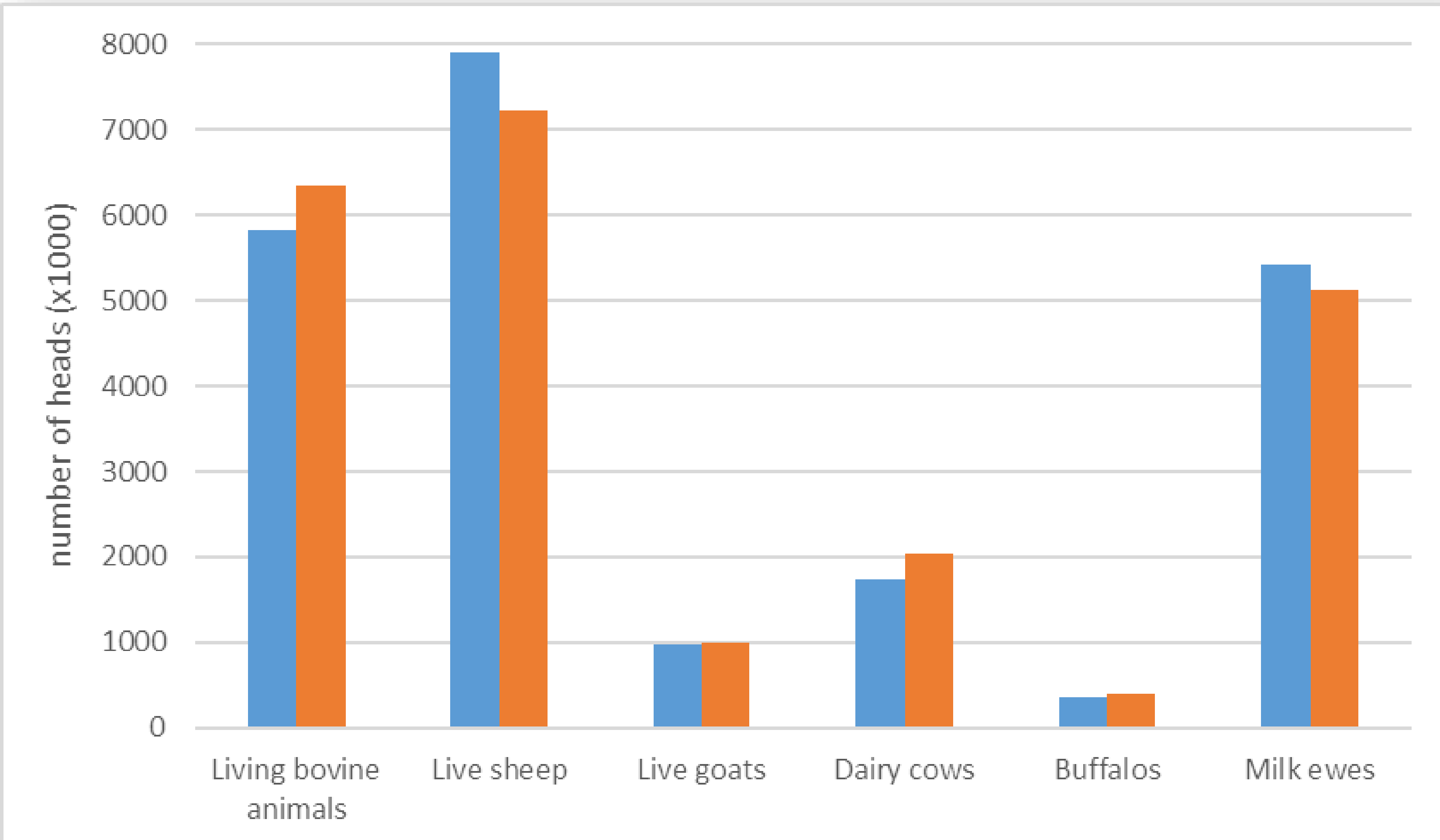
Grassland types in Italy



Permanent Grasslands cover 3,3 million ha

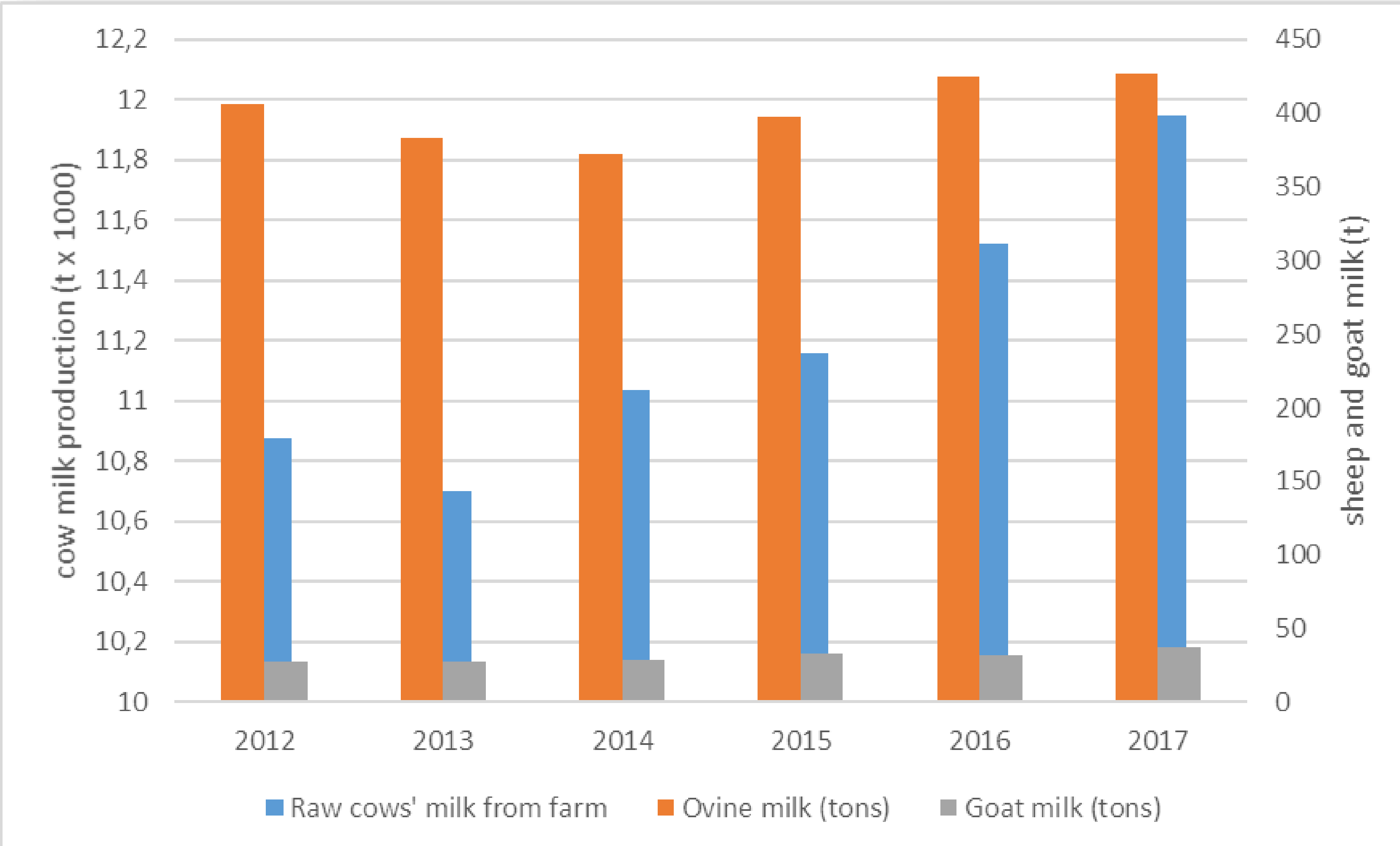
Data: Eurostat. 2013

Livestock in Italy



Eurostat, 2017.

Trend of milk production 2012 - 2017



Grasslands in Mediterranean Italy

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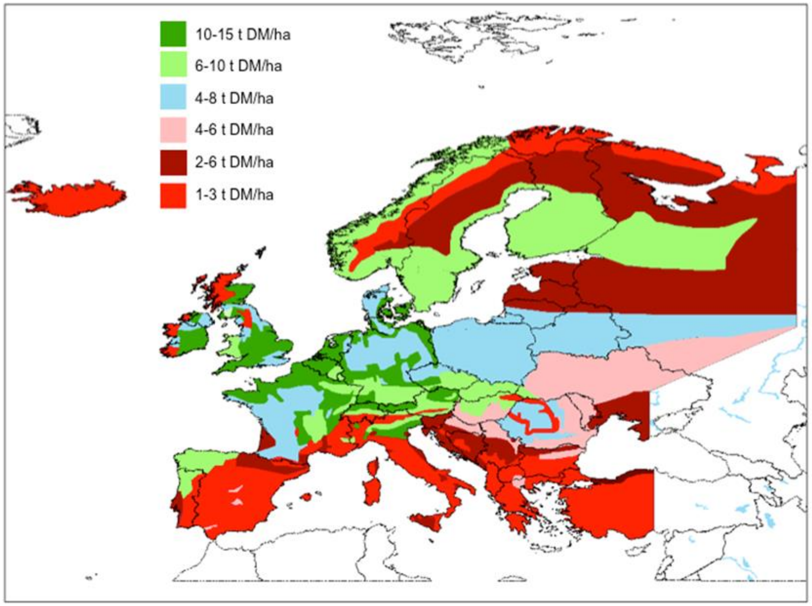
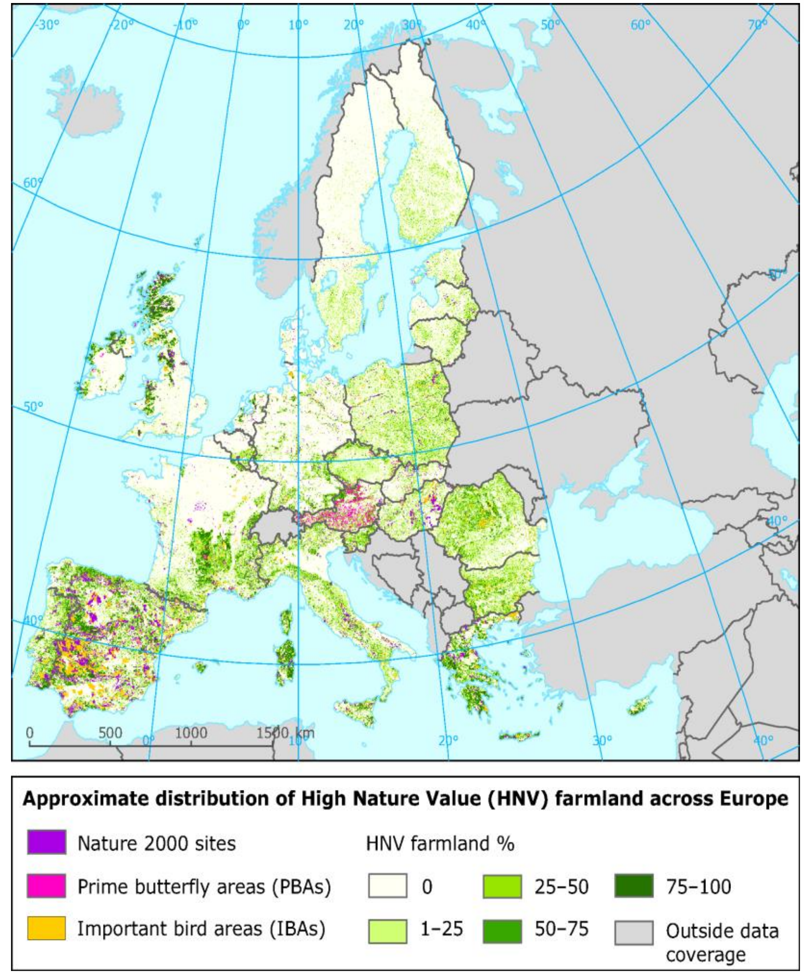
Issues concerning grasslands in Med regions

Map of potential forage production (Lee, 1983; Huyghe et al., 2014)





Med grasslands show a low production compared to the other European grasslands. Nonetheless, obtaining a higher DMY is not the main target

They have a pivotal role in the maintainance of HNV areas

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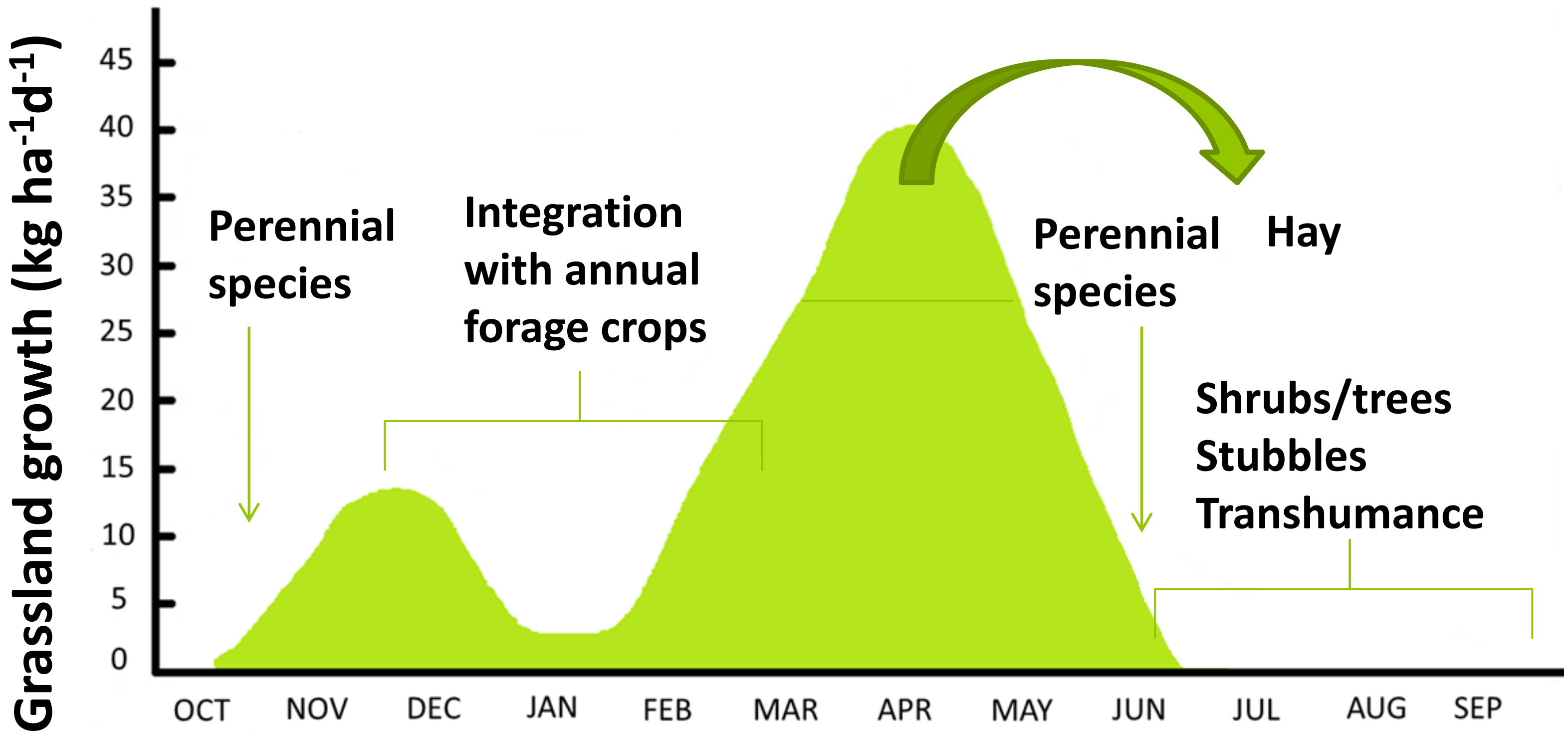
Seasonality of forage production

The most important climate trait of Med areas is the concentration of rainfall during the relatively mild winter season and its total absence during hot summer, associated to a large intra- and interannual variability.

Problem: matching animal requirements with grassland forage availability

Daily growth rate of a Mediterranean semi-natural pasture



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Grassland production

Pasture DMY (t ha-1) in six sites (average of 5 years) measured with the method of Corrall and Fenlon (1978)

Site	Altitude (m a.s.l.)	Type of soil	DMY (t ha^{-1})		DM %	Extension of forage availability (in weeks)
			Not fertilised	Fertilised		
BONASSAI	**80**	**Limestone**	**4.23**	**8.23**	**95**	**+7**
CHILIVANI	**350**	**Alluvial**	**2.77**	**5.05**	**82**	**+7**
BADDE ORCA	**600**	**Trachitic**	**3.13**	**5.52**	**76**	**+3**
PATTADA	**650**	**Granite**	**4.44**	**6.33**	**43**	**+4**
CAMPEDA	**650**	**Basaltic**	**3.92**	**6.41**	**63**	**+3**
S. ANTONIO	**650**	**Basaltic**	**2.39**	**5.38**	**122**	**+8**

From Bullitta and Caredda (1982)

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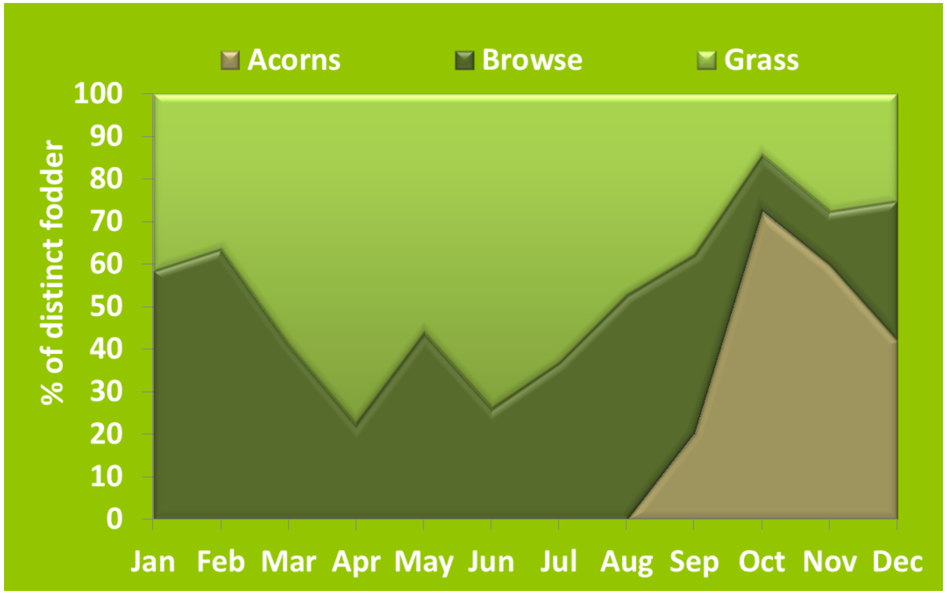
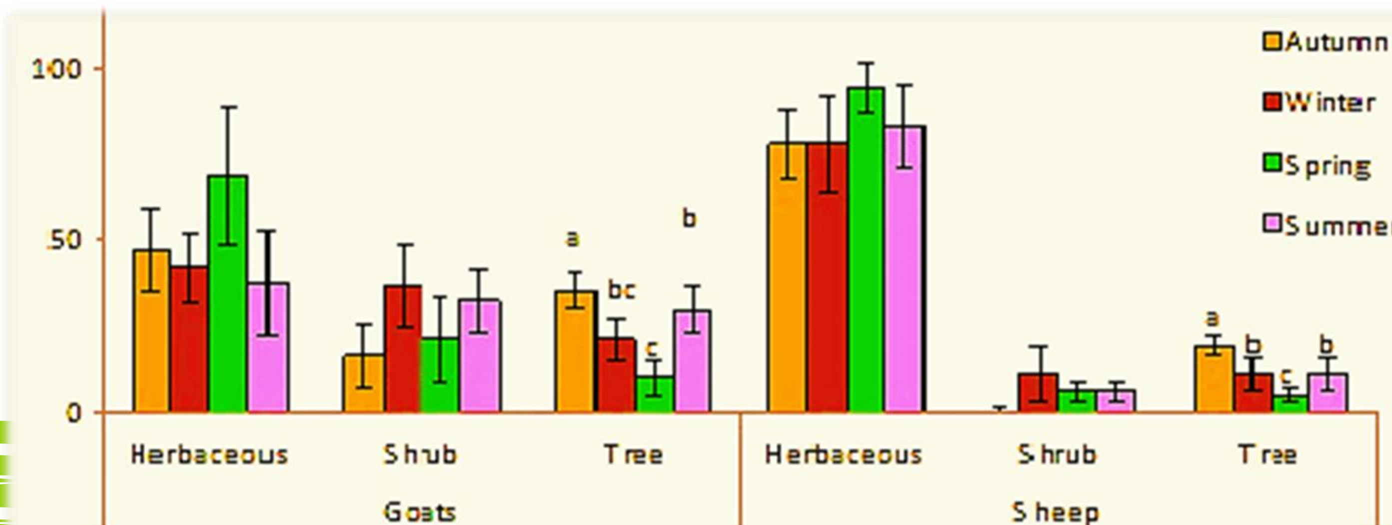
Integration of grassland resources

Seasonal Use of Forage Resources (San Miguel *et al*., 1996)



Seasonal percentage of herbaceous, shrubs and trees in the diet of goats and sheep (Castro and Fernández Núñez, 2016)



Benchmarking of grasslands

TRADITIONAL METHOD
Point quadrat method (Daget Poissonet)

Focus on pastoral resource management

Pastoral Value

Method based on the concept of pasture type: semi-natural vegetation (mainly exploited by grazing animals), homogeneous in terms of botanic composition and influenced by environmental factors and agro-pastoral management.

Pastoral Value is a synthetic index that describes the agronomic value of a pasture

PV = 0.2 Σ SCP * Si (range: 0 – 100)

SCP = Specific Contribution of Presence for each species

Si = Specific index of a single species (score from 0 to 5)

- **correlation pasture production and stocking rate capacity**
- **comparison of different pasture types within a region**
- **useful also in pasture management for extra-productive purposes**

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European Union's Horizon 20
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Practices to improve grasslands

LEGUMES

Favourable environment to grow legumes (mild winters, long sunshine periods)

High N biological fixation: 70 to 200 kg N ha^{-1} year^{-1} under rainfed conditions

Animals grazing during all the year

The cheapest utilization; recycling of 70 to 80 % of the ingested nutrients

LEGUME-RICH PASTURES AND FODDER CROPS PRODUCED AND UTILIZED AT LOW COST !!!

Practices to improve grasslands

Pastoral annual legumes with hard seeds for permanent pastures

Trifolium subterraneum

Trifolium resupinatum

Medicago polymorpha

Ornithopus compressus

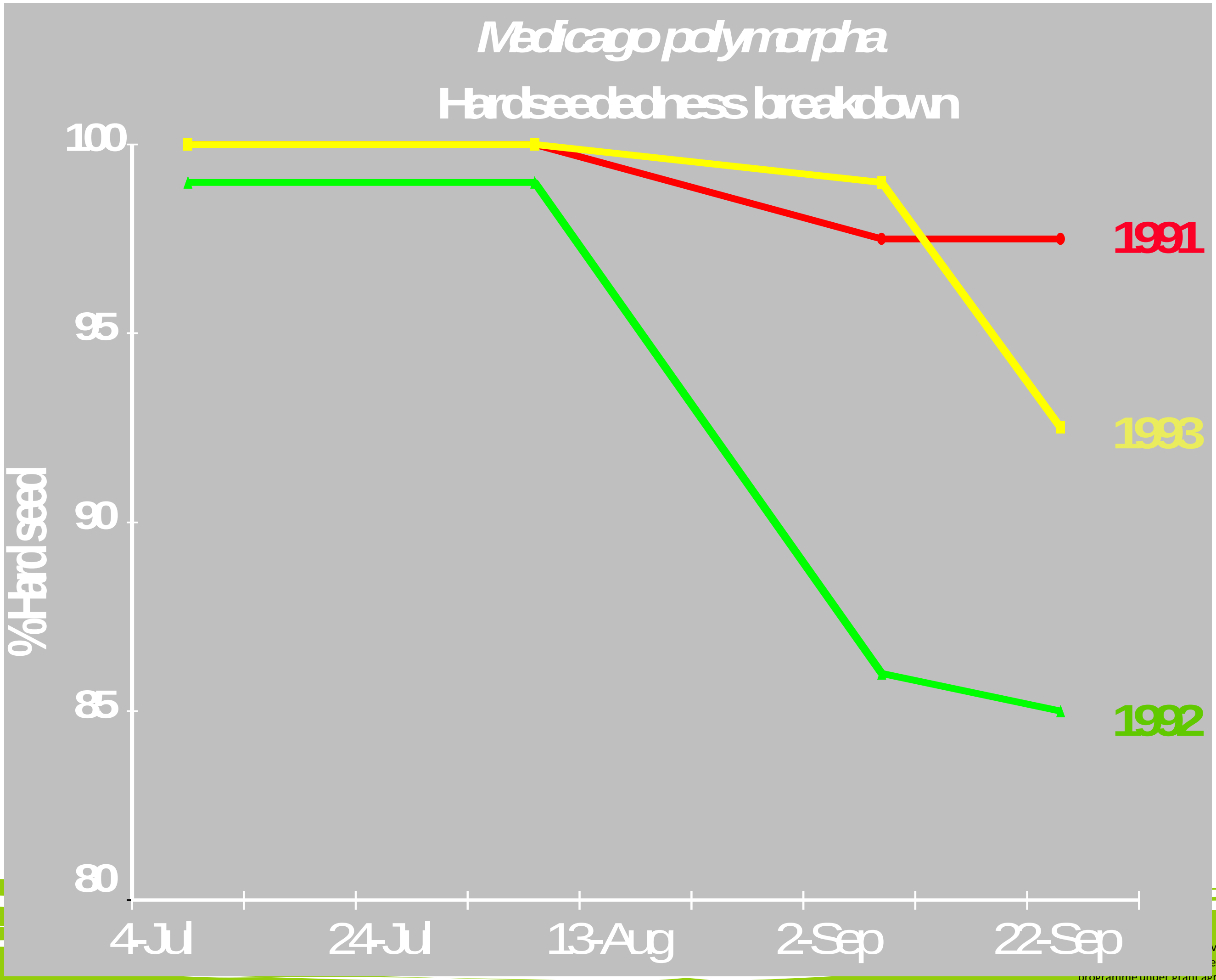
Biserrula pelecinus

Drought escape is the main adaptive strategy that exhibit for surviving during the dry period as seed

High tolerance to grazing

The Inno4Grass Project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727368.

Variation in the pattern of hard seed breakdown of the same *Medicago polymorpha* accessions in relation to the year of seed production (Porqueddu *et al.*, 1996)

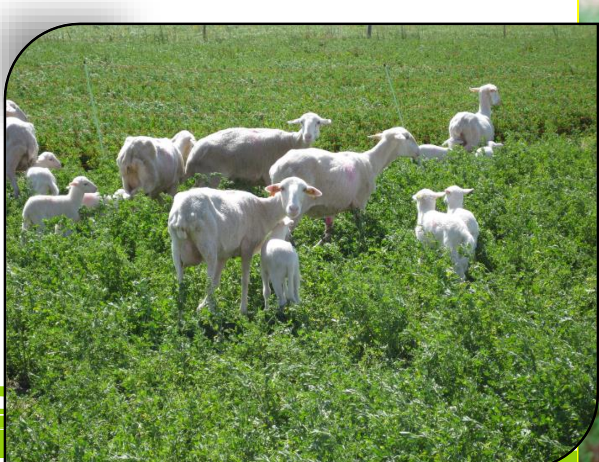


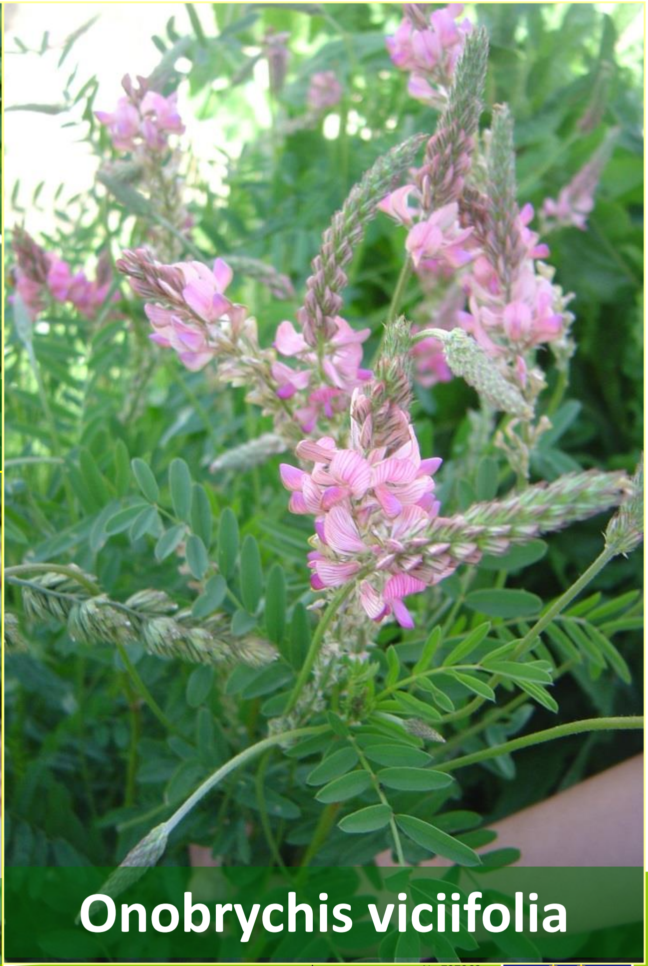
...ved funding from the ...earch and innovation programme under grant agreement No 727368.

Practices to improve grasslands

Perennial legumes for rainfed grasslands

- Drought tolerant species
- Flexibile use (grazing/ hay)
- Presence of beneficial secondary compounds
- Multi-use





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Practices to improve grasslands

Plants containing condensed tannins (<5%)


Sheep grazing on sulla pasture in Sardinia
Sheep grazing on sulla pasture in Sardinia

Beneficial effects

- Lower protein degradation rate in the rumen
- higher amino acid absorption
- lower burden of intestinal parasites and flies attacks

- **Higher animal production**
- **Lower enteric CH_4 generation**

From Waghorn and Hegarty, 2011

Table 3
An illustration of changes in emissions intensity (Ei; CH_4/kg live weight gain) in sheep fed diets of varying quality.

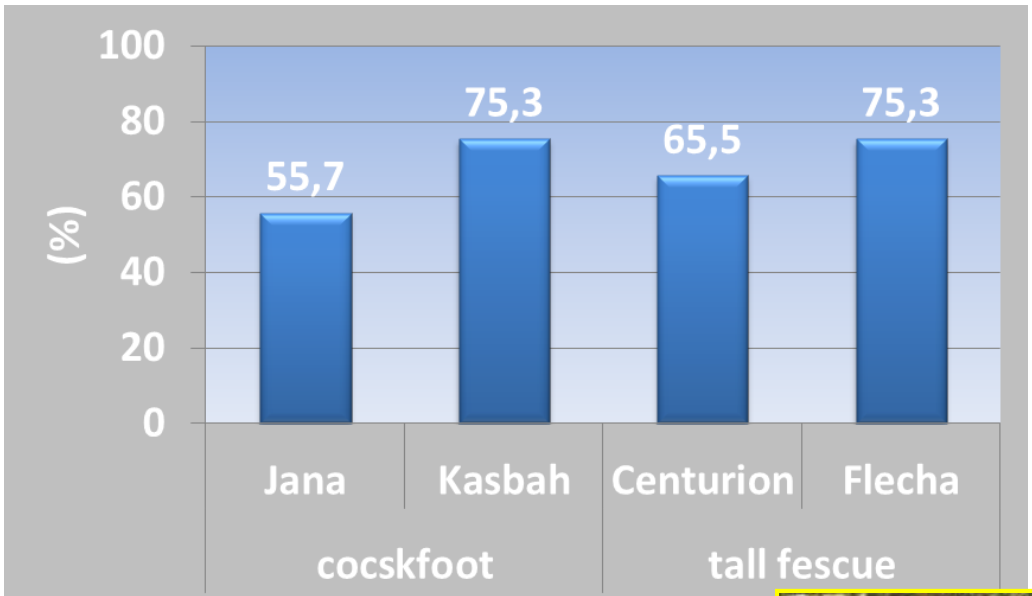
Dietary ME (MJ/kg DM)	Forage	Gain (g/d)	Methane (g/kg DM intake)	Feed:gain ratio (kg DM intake/kg gain)	Ei (g/kg gain)
10.0	Ryegrass pasture	100	24.0	13.6	300
11.0	Ryegrass pasture	150	22.0	9.4	210
12.0	Ryegrass pasture	200	21.0	7.5	160
11.5	Lucerne	250	20.0	6.7	130
12.0	Sulla[a]	300	17.5	6.2	110

ME: metabolisable energy; DM: dry matter.
Calculated CH_4 emissions per unit of liveweight gain from growing lambs fed forages with a range of feeding values (from Waghorn and Clark, 2006).
[a] Sulla (*Hedysarum coronarium*) contains condensed tannins.

Practices to improve grasslands

Persistence in perennial grasses for permanent pasture

Average row cover (%) after 6 years. Mean values among six sites in Mediterranean environments



Survival after summer

Dactylis
temperate origin

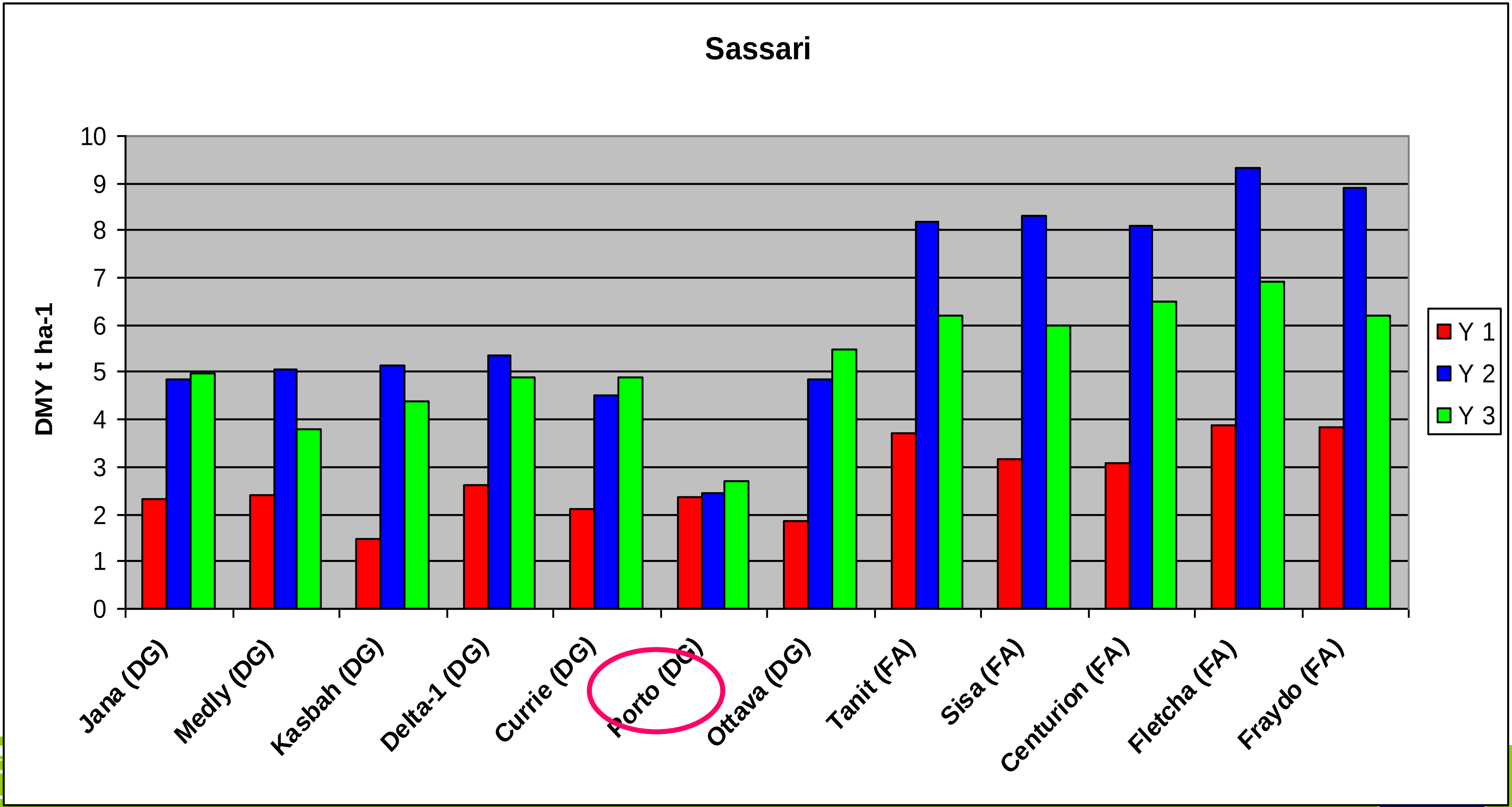
Dactylis
Med origin

ng from the
innovation
No 727368.

Practices to improve grasslands

DMYs and persistence of native grasses adapted to Med rainfed conditions

Dry matter yield of cultivars (t ha^{-1}) during a three-year field trial. From Porqueddu *et al*. (2008) and Annicchiarico *et al*. (2013)



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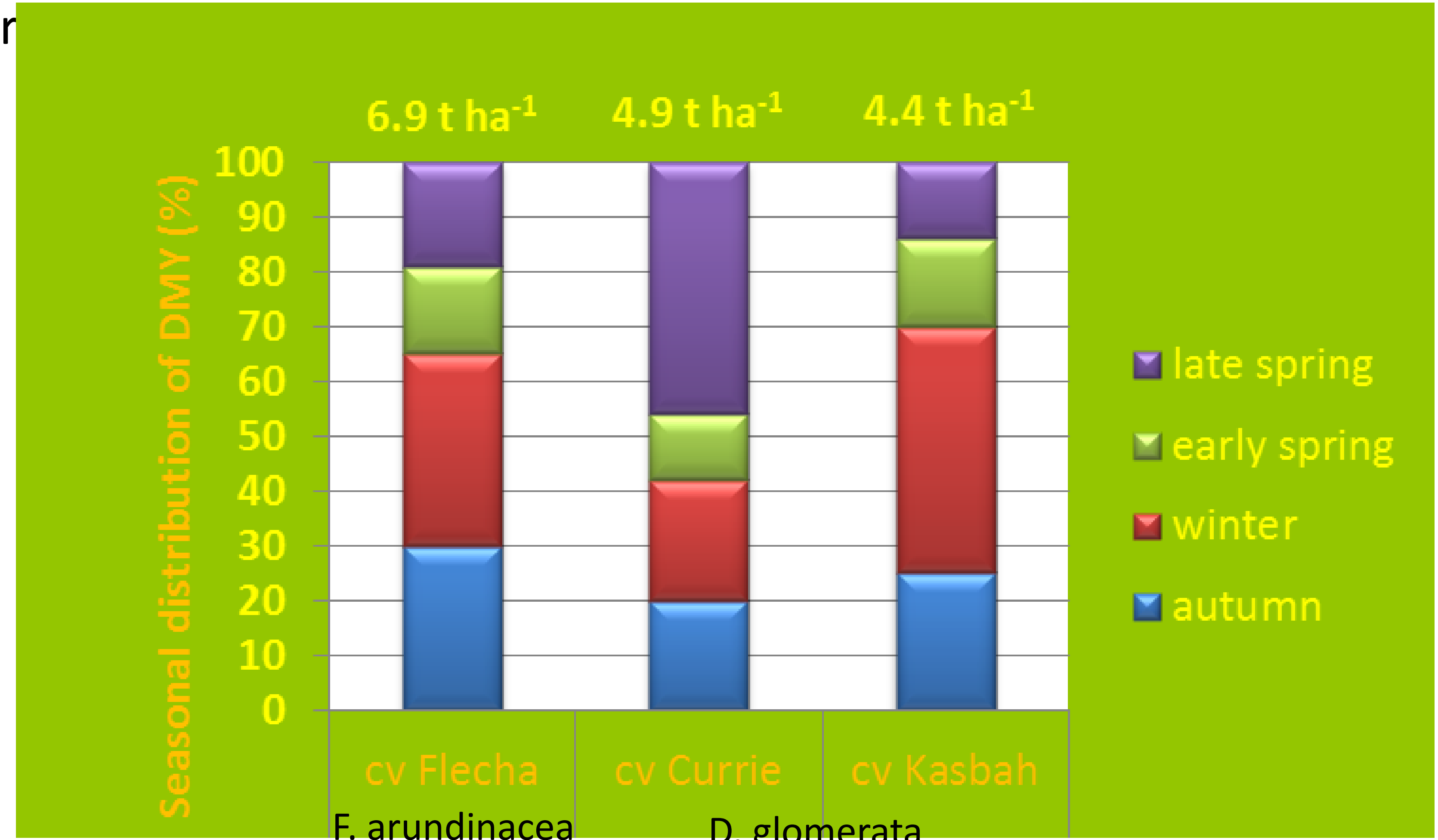
Practices to improve grasslands

Seasonal production of native grasses adapted to Mediterranean envir



F. arundinacea D. glomerata

Porqueddu *et al*. (2008)

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Practices to improve grasslands

Use of mixtures of adapted native grasses and legumes

EU Action COST 852 “Quality Legume-Based Systems for Contrasting Environments”

Species belonging to 4 functional groups:

- **Grass / Legumes**
- **Fast establishing / Slow establishing (= annuals/perennials)**

NATIVE SPECIES (Dry Mediterranean mixture)

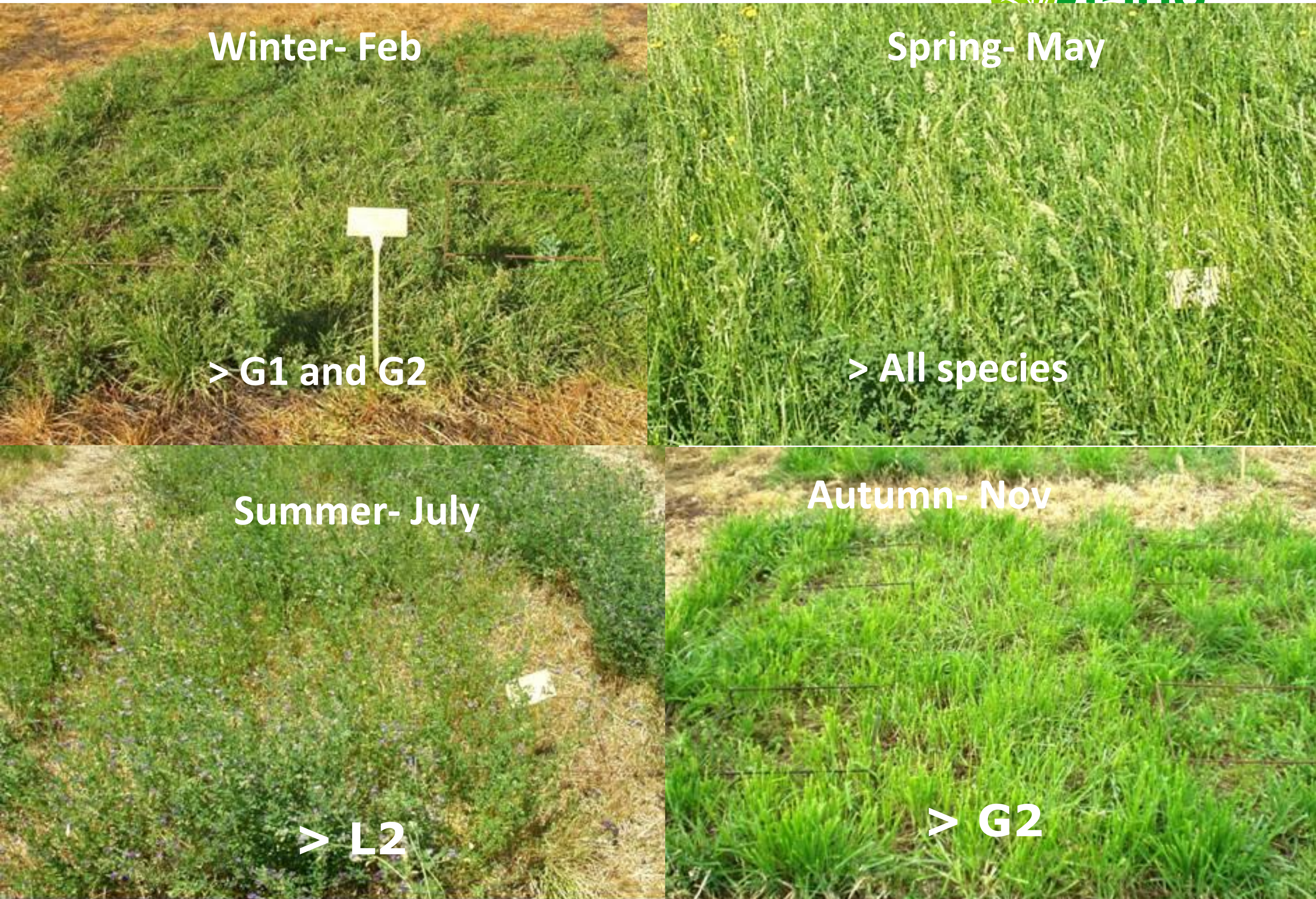
G_1= *Lolium rigidum* Nurra

G_2= *Dactylis glomerata* Currie

L_1= *Medicago polymorpha* Anglona

L_2= *Medicago sativa* Surigheddu

Extended seasonal forage distribution



Practices to improve grasslands

Improving forage quality with the use of native species-based mixes

Plot	CP	NDF	IVDMD
L2 mono	20.0	42.9	69.8
centroid	18.5	47.5	67.8
dom G2 and L2	18.4	48.0	67.6
dom L2	18.4	46.2	69.1
dom L1 and L2	18.1	47.1	68.1
dom G1 and L2	17.9	48.0	66.9
dom G2 and L1	17.7	46.8	68.2
dom G2	17.6	48.7	66.9
dom G1 and G2	17.5	47.3	68.2
dom G1	17.3	46.3	67.9
dom L1	17.2	47.0	68.6
dom G1 and L1	15.8	46.2	66.8
L1 mono	14.8	42.1	68.1
G2 mono	14.3	59.2	58.5
G1 mono	12.9	47.1	64.7
mean mono	**15.5**	**47.8**	**65.3**
% change mono/centr.	**19.3**	**-0.7**	**3.9**

G1, G2 = grass
L1, L2 = legume
1= fast establishing species
2=slow establishing species

Average values of 5 harvests along the year

Maltoni et al. (2007)

Establishment and management

<u>Seed innoculation</u>: prior to sowing, the seeds of each legume species may need innoculation with specific and highly effective *Rhizobium* strains, in order to enhance symbiotic N fixation, making the system self sufficient in this important nutrient

Nutrient management

Legume-based pastures are self-sufficient in N but require adequate applications of other macronutrients, particularly P (at establihment and top dressed once a year) and if needed also other macro (K, Ca, S, Mg) or micro-nutrients (Mo, B, Zn, Cu, Fe, Co)

Sowing

Early in the Autumn (ideal soil temp. >16º C),

over a superficially prepared seed bed (minimum tillage)

Grazing management

Grazed during all the year with stocking rates adjusted to mean herbage yields

Building a seed bank in Spring

Deep grazing in Summer

Natural regeneration after the Autumn rains

programme under grant agreement No 727368.

Grasslands in Italian Alps

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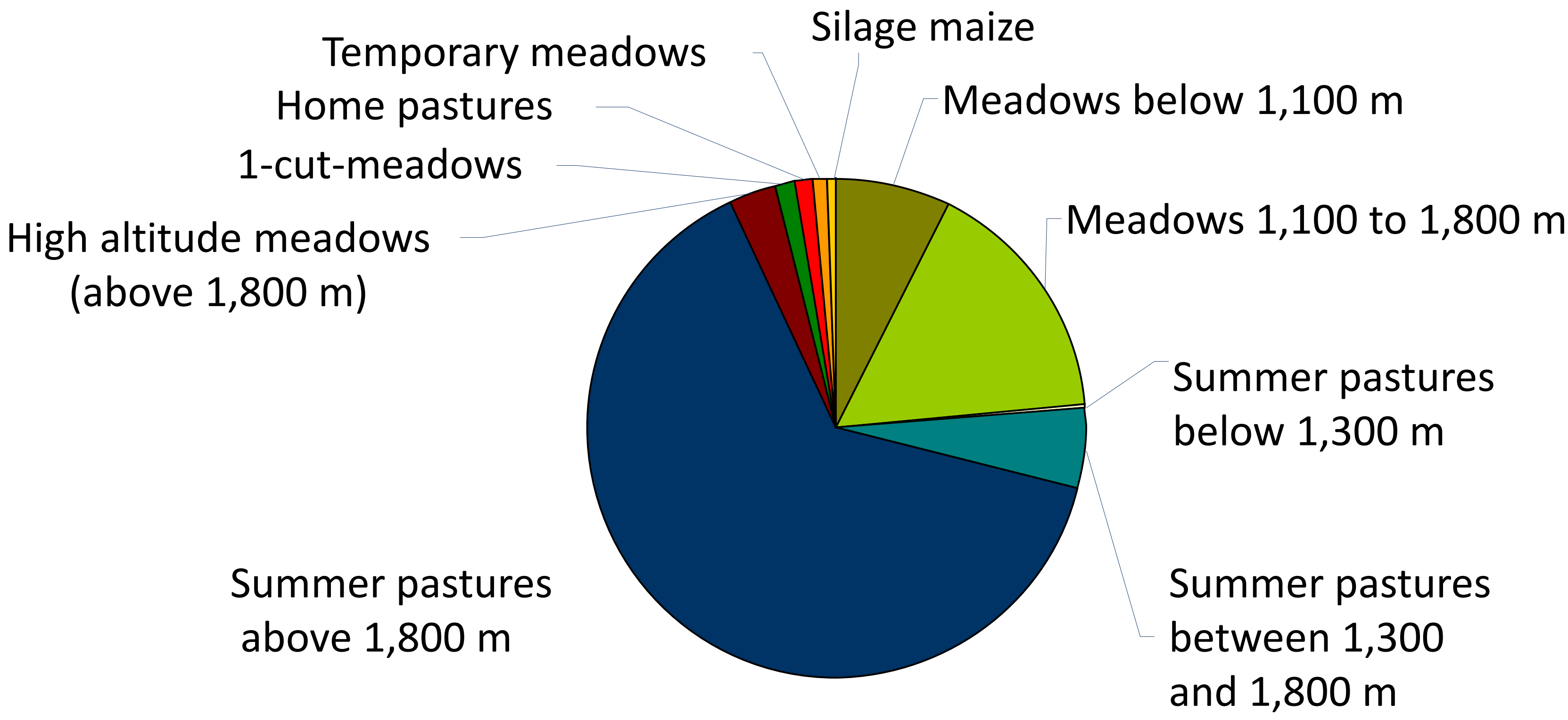
Fodder areas in South Tyrol



Source: Peratoner *et al.* 2011 (mod.)

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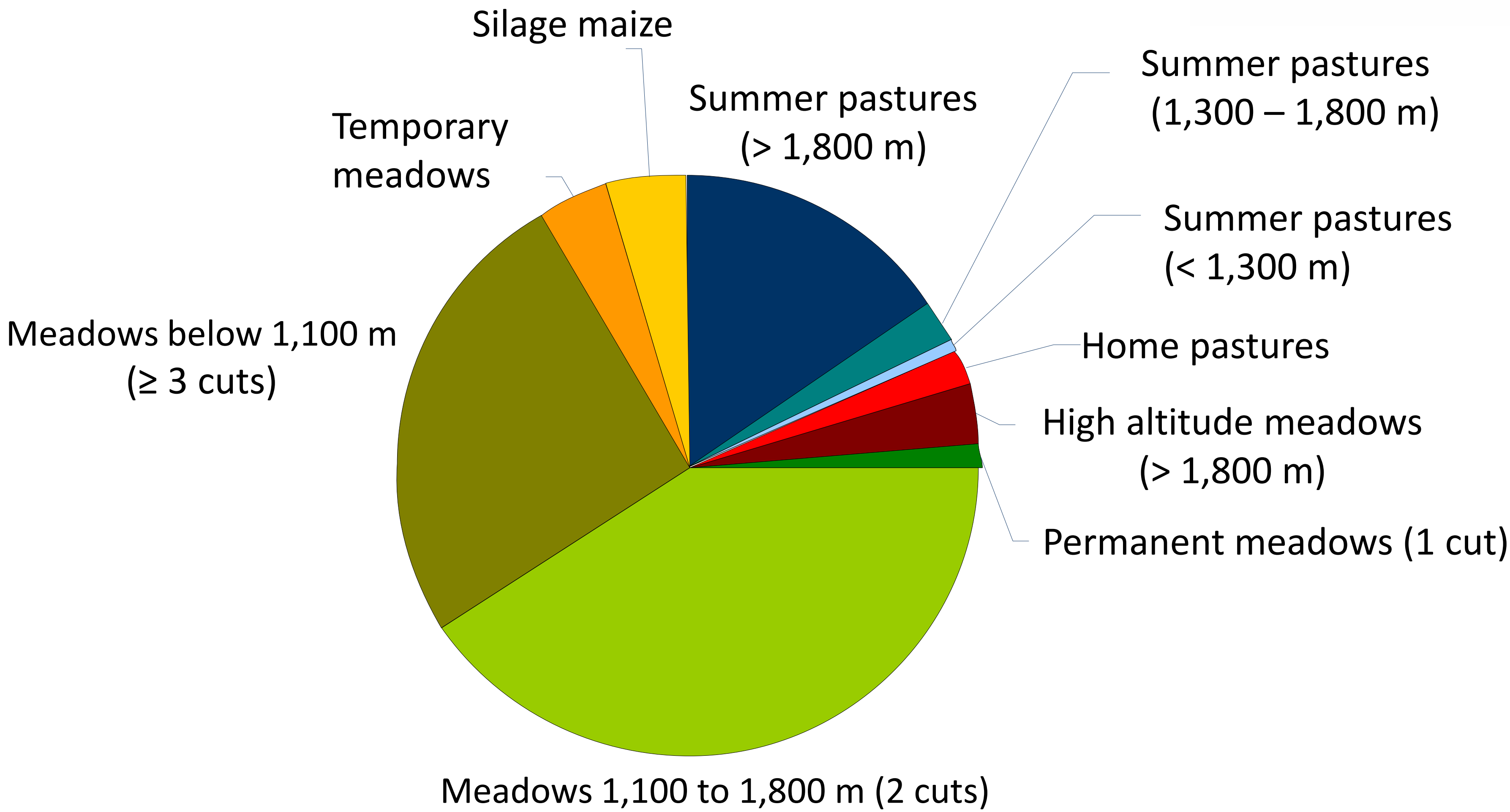
Contribution of grasslands to the overall forage production in South Tyrol



450,113 tons DM/year

Source: Peratoner *et al.* 2011 (mod.)

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Difference between meadows and pastures

- Meadows: the whole aboveground biomass is removed at once above a certain cutting height (more vulnerable to stress factors after the cut)

- Pastures: by grazing, animals remove the aboveground biomass near to the ground, trample the plants and fertilise the vegetation with dung and urine

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Elements of grazing - Selective grazing

- Animals have definite preferences for some components in the sward (→ see the slide on palatability)
- Accessibility (how easily the plants can be accessed by the animals) increases attractiveness for the animals, fungal diseases (i.e. rust infections) lower it
- Species distributed in the upper layer of the sward's canopy are more likely to comprise a higher proportion in the diet
- Systematic selection of certain species by grazing can change the long-term composition of the sward → species intensively grazed than other are disadvantaged, the ungrazed ones have a selective advantage
- Following selective grazing, patches of ungrazed vegetation should be cut/topped to prevent further spreading of ungrazed species and ensure uniform regrowth of the sward. If there is a large amount of biomass, it should removed from the field, otherwise it could rot and adversely affect sward growth and forage palatability
- Animals learn (usually the young ones from the older ones) → known plant species are more easily accepted than unknown plants

Source: Frame & Laidlaw 2014

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Animal species and selective grazing

- Prehension: cattle tears off bunches of herbage, gathering them with their prehensile tongue, small animals with narrow muzzle select single plant parts and have prehensile lips.

Animal	Forage selection	Grazing of tall herbage	Grazing of shrubs	Grazing of thistles*	Biting depth
Highly specialised dairy cows (i.e. Holstein-friesian, Brown)	low	yes			-
Dual-purpose breeds (i.e. Simmental, Grey) cattle breeds	low	yes	sometimes		-
Heifers	low	yes	sometimes		-
Young cattle	low	yes	sometimes		-
Sheep	medium		sometimes		++
Goat	high		yes	yes	+
Horse	high**	yes**	sometimes		+

* *Cirsium* sp., *Carduus* sp., *Carlina* sp.

** Horses have higher need for fibre-rich forage and can graze plant stands rich in grasses up to the emergence of inflorescence, but they become very selective beyond this phenological stage (Buchgraber & Gindl 2004); with bot top and bottom incisors they can graze very close to the ground; according to Frame & Laidlaw they prefer short herbage

Source: Buchgraber & Gindl 2004, Ziliotto et al. 2004, Frame & Laidlaw 2014

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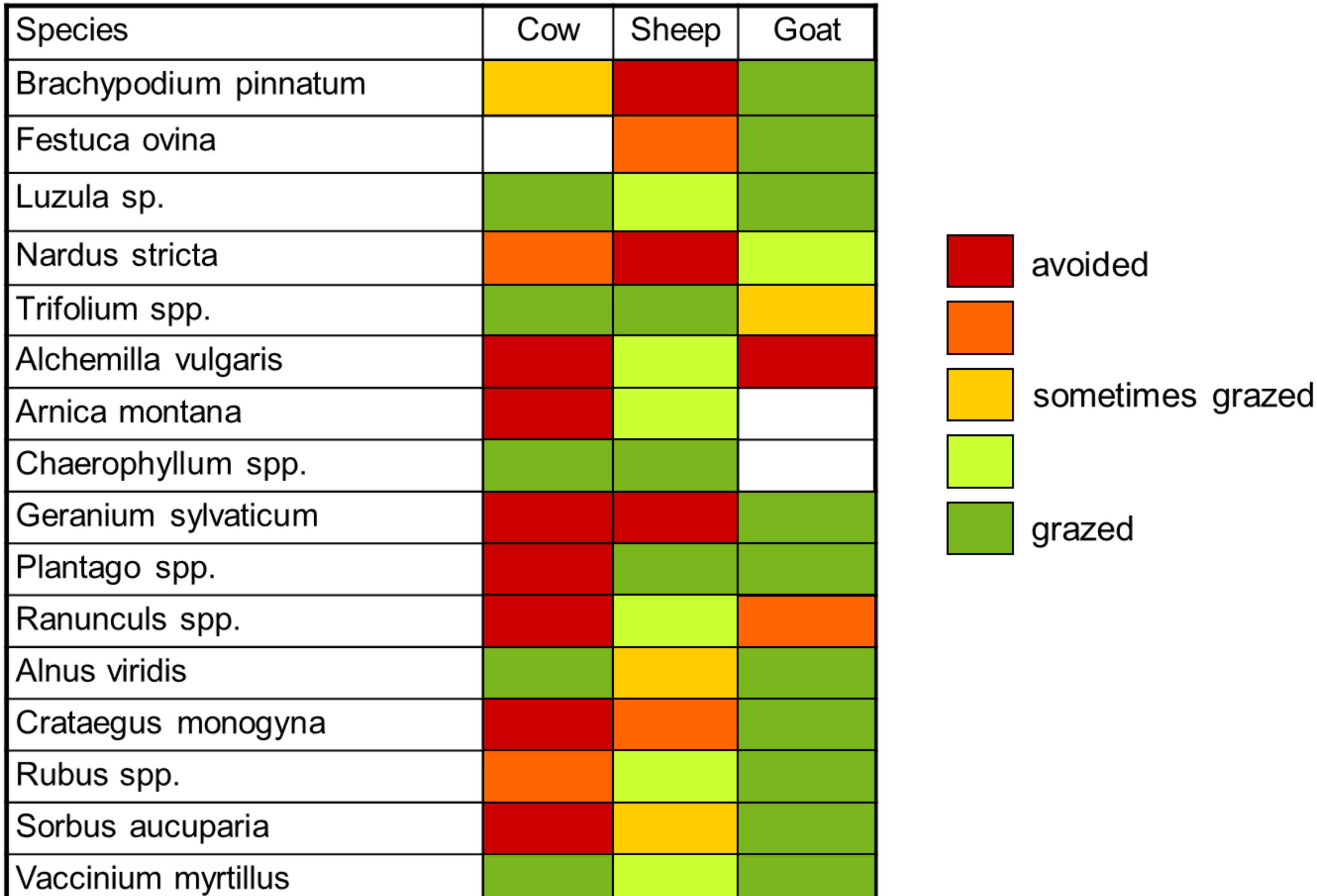
Grazing/browsing selectivity of different animal species of grasslands to the overall forage production in South Tyrol



Source: Schneider et al. 2015 (mod.)

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Contribution of grasslands to the overall forage production in South Tyrol

Grasses with coarse leaf texture

Rhododendron sp.

Calluna vulgaris
Vaccinium sp.

Shrubs

Senecio alpinus (=Senecio cordatus =Jacobaea alpina).

Veratrum album

Poisonous plants

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When should grazing start?

- It depends on the adopted grazing method
- In general: at latest when the upper stem node is 10 cm above soil ground (about 15 cm plant growing height, grasses are still before booting); not before the payback time has been concluded (3 leaves stage of pasture-suited grasses – reserves have been replenished)
- Quick method to check grass availability for grazing using the average height of vegetation in extensively managed pastures (don't take unpalatable species into consideration)
  - Between half-calf and knee or higher (30 cm or more) → too much grass available
  - Half calf (about 20 cm) → plenty of grass available
  - Ankle (about 10 cm) → grass available
  - Boot sole (3 cm or less) → no grass available for grazing

Source: Steinwidder and Starz, 2015; Pasut 2014, mod.

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Elements of grazing - contamination by dung and urine

- (50) 75 to 95% of the nutrients ingested by grazing animals may be returned to the soil (theoretically even more, if high amount of supplements are supplied to the livestock).
- Dairy cow → about 0.6-0.7 m^2 covered daily with dung, 3-5 m^2 with urine; sheep → about 0.05 to 0.07 m^2 covered daily by dung.
- With the exception of goats, dung is usually concentrated on night-lying areas, feeding troughs and tracks, water troughs, gateways and tracks.
- Herbage contaminated by dung or growing in the vicinity of dung patches becomes unattractive to livestock. This effect is greater at low grazing pressure and if livestock is not accustomed to it.
- Slurry applications depress acceptability until slurry is washed off by the herbage by rain.
- Contamination by dung is increased at high growing by tall vegetation (more than 20 cm → late grazing start)

Source: Frame & Laidlaw 2014; Cavallero & Ciotti 1991

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Effects of trampling (=treading)

- Trampling by livestock hooves has mainly negative effects on the soil (soil compaction, mechanical damage to the plants).
- Hoof stresses and the negative effects are enhanced
  - livestock weight (1.2-3 kg/cm² pressure for cattle vs. 0.8-1 kg/cm² for sheep)
  - by walking and running actions
  - loafing and lying about
  - wet weather
  - slope
- Species
  - with profuse tillering (i.e. Lolium perenne)
  - with folded leaf structure (i.e. Lolium multiflorum, Festuca pratensis and Phleum pratense are less suited)
  - with creeping growth habit by stolons (Poa trivialis) or rhizomes (Poa pratensis) → better regeneration after damages
  - prostrate rosette-plants
- Trampling and the subsequent soil contamination reduce the attractiveness of herbage for grazing

Source: Frame & Laidlaw 2014; Cavallero & Ciotti 1991

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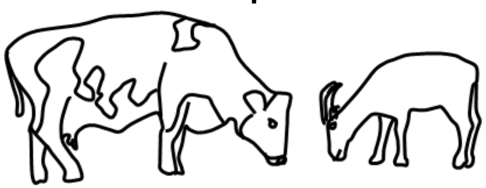
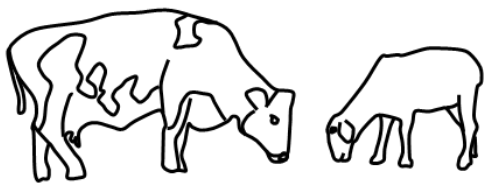
Mixed grazing

- Aim: to take advantage of the complementarity of the grazing behaviour of different animal species
- Lead-follower-system: highly productive animals start grazing 1-2 days before less productive animals

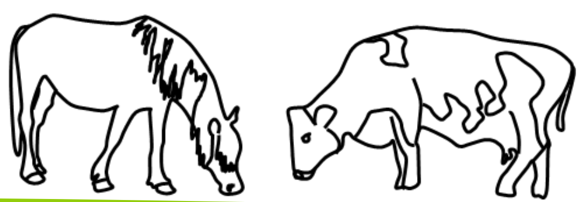


Combination of grazing and browsing animals and of a selectively grazing species with a less selective one



Combination of a selectively grazing species with a less selective one. Reduced parasites pressure.

Good tolerance between species, but increase of parasite pressure (same gastrointestinal worms for both species).



Combination of different grazing behaviours. Reduced parasites pressure.

Source: Schneider et al. 2015

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Methods to estimate forage production on pastures

- Ingested herbage can be estimated by exclusion cages: animals are prevented from grazing certain areas (1 to 4 m^2). Biomass production is measured within the exclusion cages at the end of the grazing period and residual herbage is subtracted by it.

- The biomass available at a certain point in time is measured by means of a rising plate meter: the compressed sward height is measured using a device made out of a stick on which a plate is held at a certain height by the plant biomass. A correlation between compressed sward height and herbage biomass can be established. Other simpler methods are possible as well.

- The production of a pasture during the growing season can be estimated by the Corral-Fenlon-method: a number of plots equal to the duration in weeks of the grazing cycle (usually 4 weeks) is established and each plot is harvested each week in sequence. For each plot, a mean growth rate for the period between one cut and the next is computed and the growth rates of all plots are averaged.

Source: a) P. D'Ottavio

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Methods of grazing: Continuous stocking

- Free-range grazing of stock on an area
- Maximum selectivity of grazing animals: avoidance of species of low palatability, high amount of necromass at the end of the grazing season (low proportion of grazed forage on offer → utilisation coefficient 0.3-0.6), deterioration of forage quality along the growing season (phenological advance, best spots are grazed first)
- Less capital and labour needed for installation and operations
- Good performance of single animals at the beginning of the grazing season, but lower productivity per ha. With the advance of the season the productivity drops because of overgrazing of the most favourable areas, the lack of young, leafy grass at the avoided areas as well as an increased need of looking for suited grazing areas over longer distances
- Negative effects can be mitigated if a herder leads the animals towards targeted grazing areas (i.e. following an increasing altitude gradient)
- Need for maintenance measures at the end of the season to prevent spread of weeds and shrubs
- Not suited to farms with small scattered fields

Source: Frame & Laidlaw 2014; Buchgraber & Gindl 2001; Ziliotto et al. 2004

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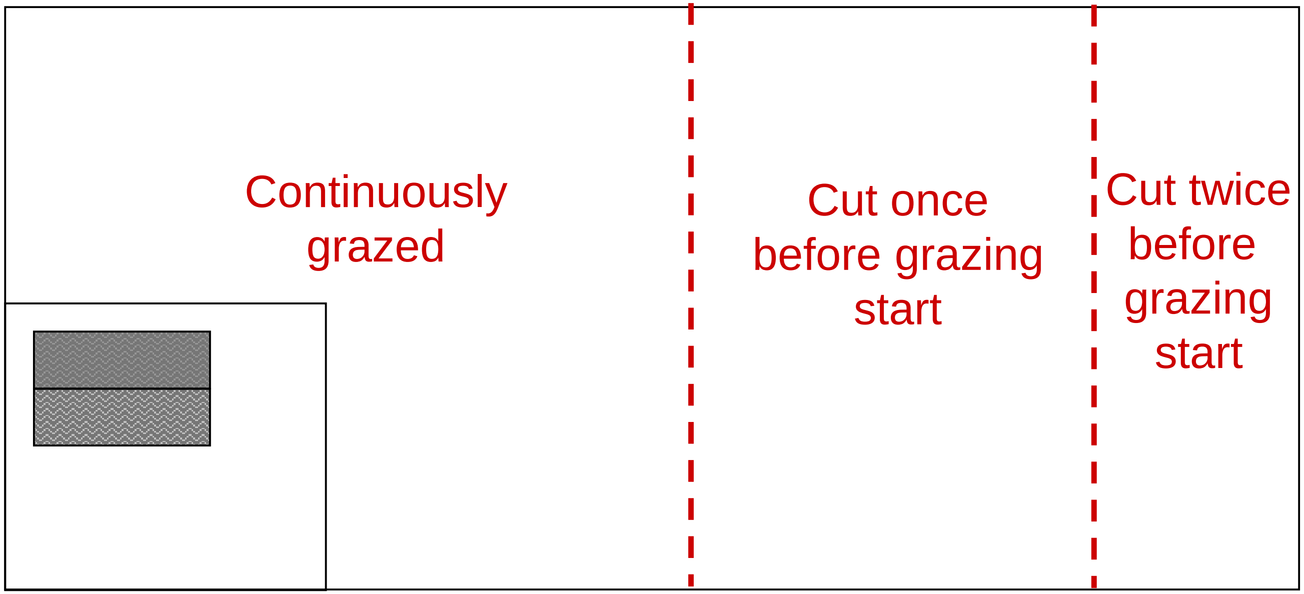
Methods of grazing: Continuous variable stocking (including the so-called “Kurzrasenweide” = “short sward grazing”)

- A target average sward height is fixed and the stocking rate is adjusted changing the grazed area in response to the deviation from the target sward height.
- A buffer grazing area is used to adjust the area to the livestock numbers.
- Ungrazed areas can be cut for forage as the vegetation gets old.



Source: Frame & Laidlaw 2014, Schmid and Kessler 2015

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Methods for measuring sward height

Graduated stick
(uncompressed height)

Plastic lid method
(slightly
compressed height)

Rising plate meter
(compressed height)

Source: Steinwidder and Starz 2015

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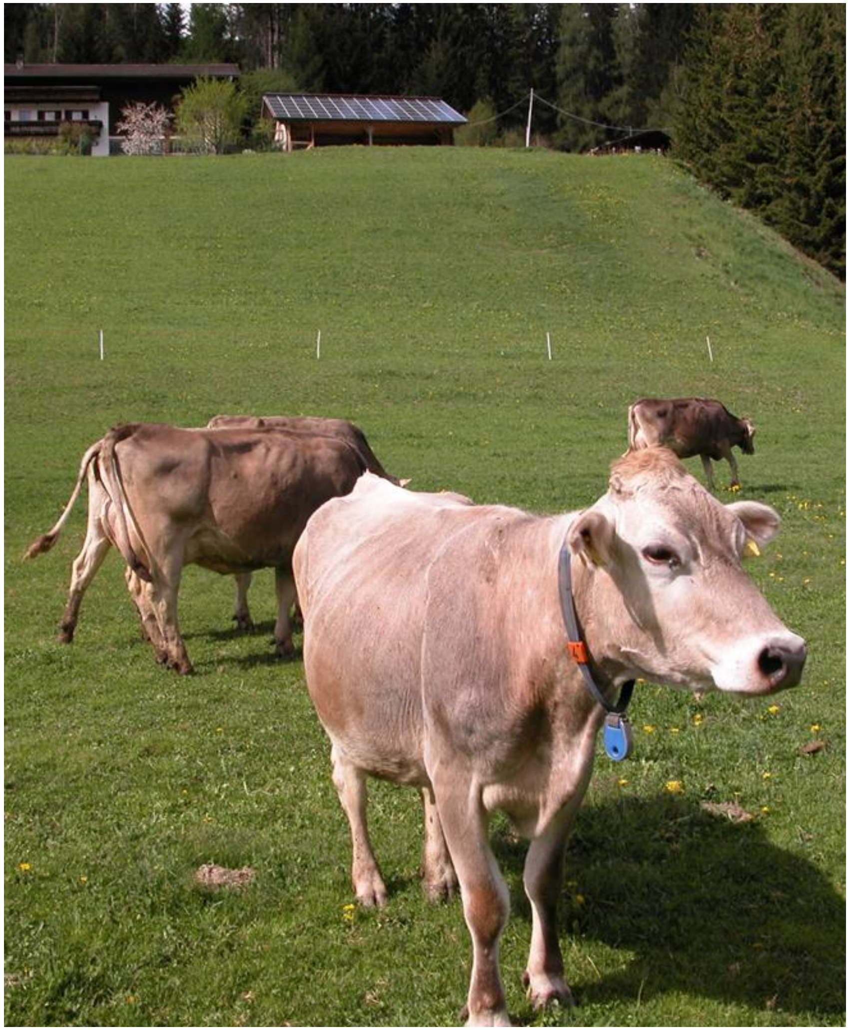
Methods of grazing: short sward grazing

- Target growing height: 6-7 cm in spring and 7-8 cm during summer (uncompressed height)
- Pre-requisites:
  - Sites suitable for *Lolium perenne* and/or *Poa pratensis* (dense swards, tolerance against trampling and frequent defoliation)
  - Flat to slightly sloped pastures
  - Good water availability (soil water capacity, irrigation)



Source: Steinwidder and Starz, 2015; Schmid and Kessler, 2015

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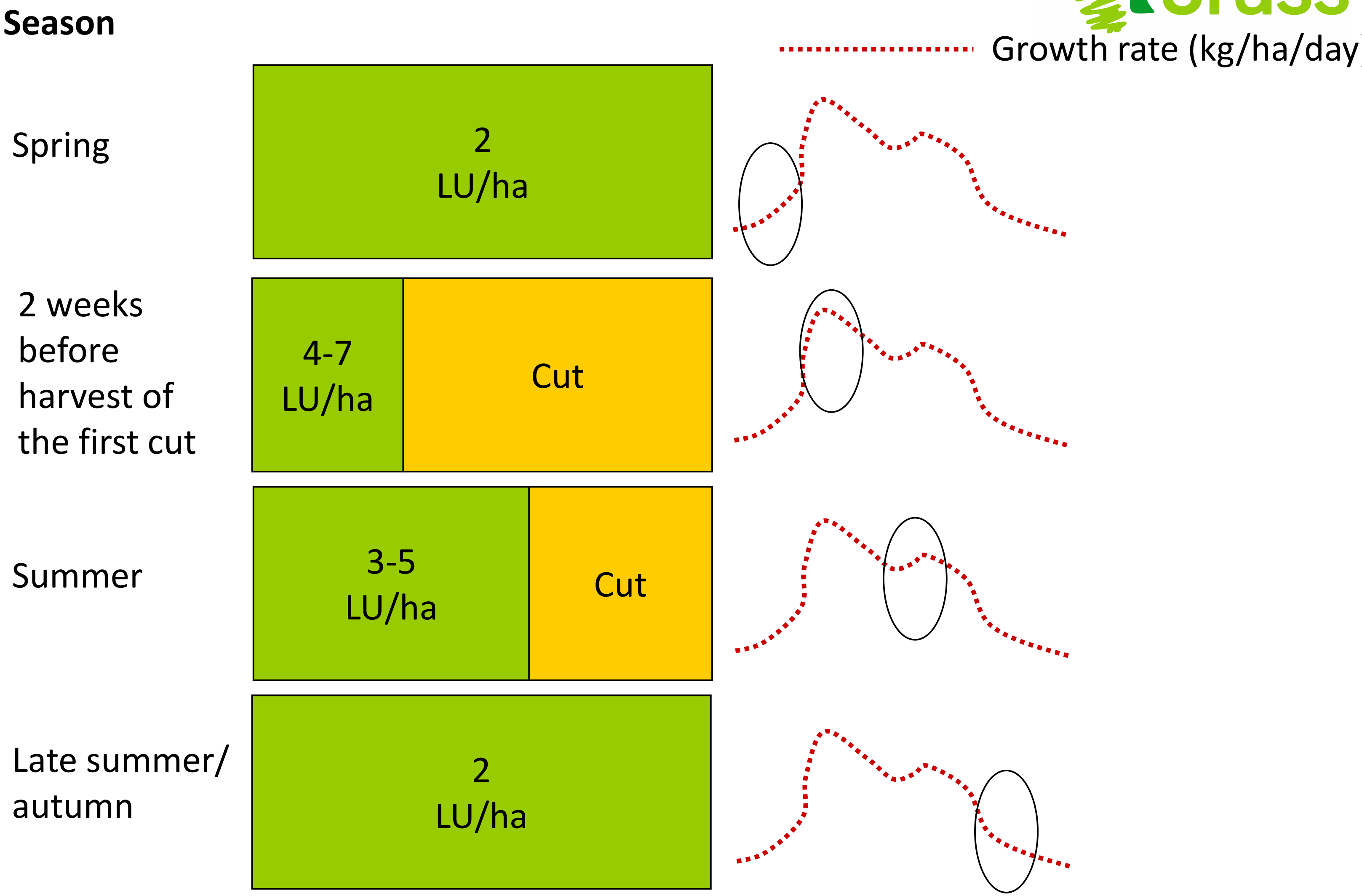
Methods of grazing: short sward grazing



Source: Steinwidder and Starz 2015, mod.

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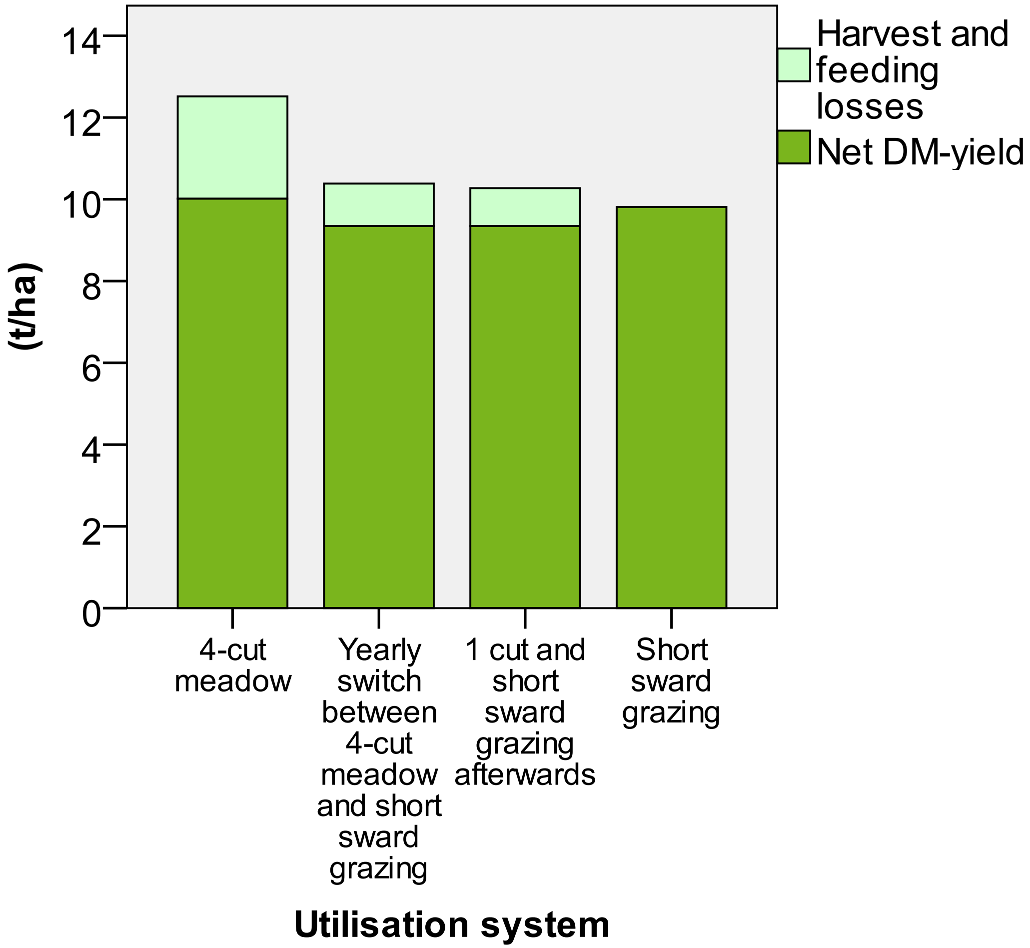
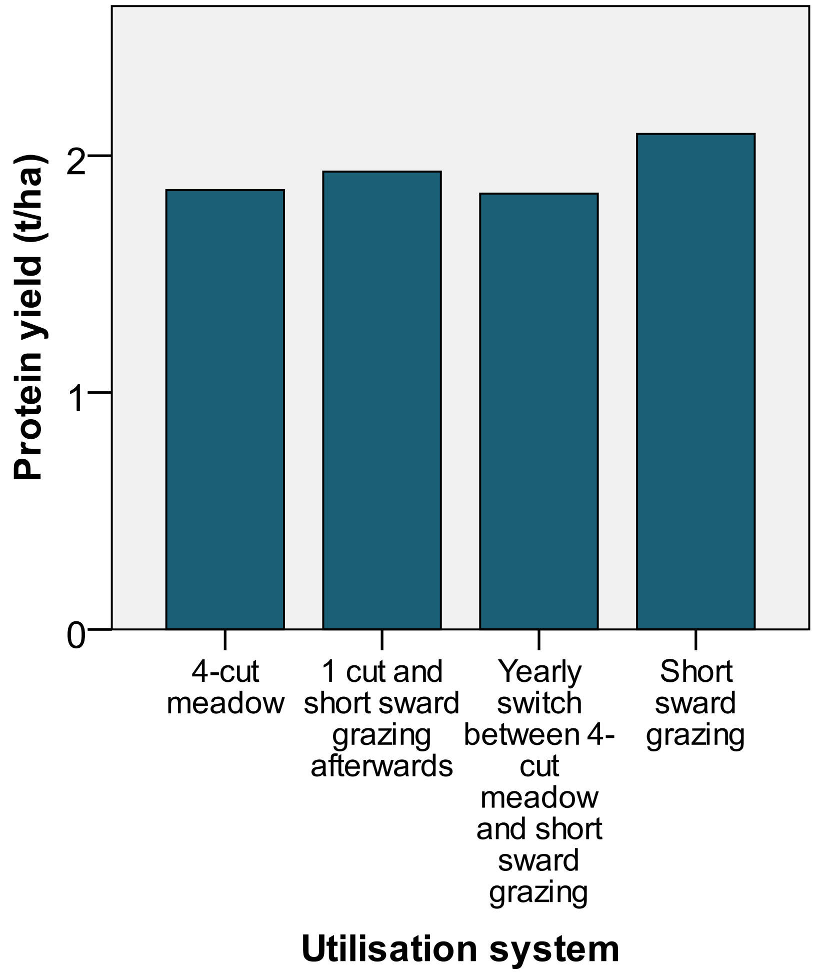
Methods of grazing: short sward grazing





Literature values of yield have been changed assuming the harvest and feeding losses being 20% of the total yield and the first cut being 37% of the yearly harvest

Source: Steinwidder and Starz, 2015 (mod.)

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Methods of grazing: Rotational stocking

- Rotational stocking: the area is divided into a series of fields or paddocks that are grazed in sequence, each use being followed by a rest period. The total length of grazing plus the rest period is called the rotational cycle.
- Paddocks are usually grazed for 2-6 days in case of dairy cattle and for 7-10 days in case of beef cattle, suckler cows, horses, sheep
- A growing height of 4-5 cm at the time the animals leave the paddock should be targeted.
- Individual animal performance is higher than in a continuous stocking system.
- A certain flexibility in management is required to react to understocking in spring (see the effects of it as discussed for continuous stocking) and overstocking in the late season (→ poor animal performance). Actions include cut and conservation of forage produces in excess (speeding up of the rotation with paddocks left out for cut and conservation) or letting young cattle graze on the paddocks in the first part of the season and then sending it to the summer pastures; buffer feeding may be required if there is forage on offer is not enough (i.e. dry periods).
- Management (→ grass budgeting, moving animals to new paddock, moving fences) and capital input high (→ fences, laneways, water pipes) can be high

Source: Frame & Laidlaw 2014; Buchgraber & Gindl 2001; Ziliotto et al. 2004

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Number of paddocks depending on the grazing time (days/paddock)

Phase	Grazing time (days/paddock)		
	3	6	10
Main growth	6-9	3-5	2-3
Late summer	12-16	5-6	3-5

Size of paddock (ha) depending on the grazing time (days per paddock)

Grazing animals	Grazing time (days/paddock)		
	3	6	10
10 dairy cows – whole day (WD)	0.3	0.5	-
10 dairy cows – 6 hours	0.1-0.2	0.3	-
10 suckler cows (dry) – WD	-	0.4	0.7
10 beef cows (400-500 kg) - WD	-	0.3	0.6

Source: Steinwidder and Starz 2015 (mod.)

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Utilisation of paddocks during the season

Source: Steinwidder and Starz 2015 (mod.)

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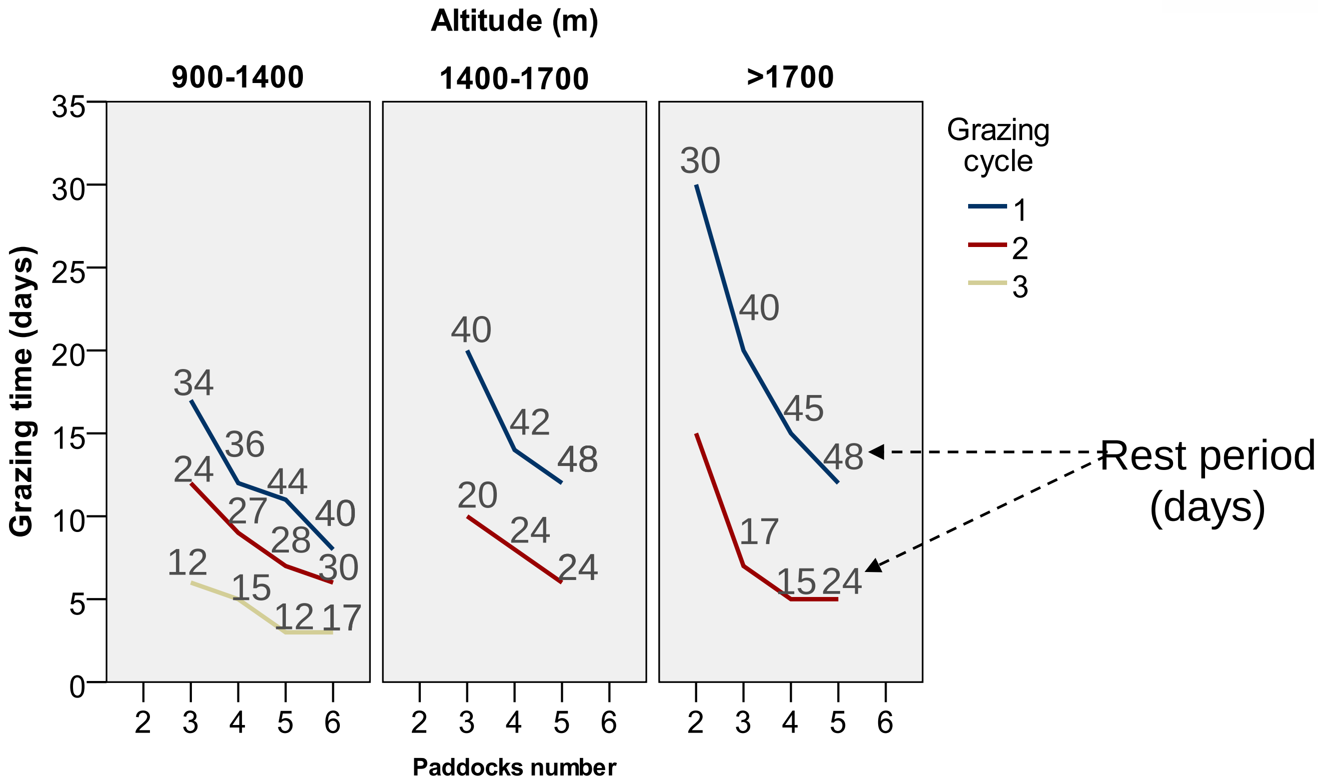
Grazing time and rest periods in rotational stocking in summer pastures



- One LU requires about 70 to 120 m²/day on favourable sites (half of it in case of partial grazing), 100-400 m²/day in alpine summer pastures, depending on the yield potential of the site
- The length of rest periods increases with the number of paddocks and decrease with the grazing cycle (→ phase of the growing season)

Source: graph → Aigner et al. 2003 (mod.), Koch 1996, Gusmeroli 2012

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Occasional grazing

- It is practised very often on meadows in autumn after the last cut (i.e. with young cattle coming back from the summer pastures)
- A very early grazing in spring is recommended to control facultative weeds such as *Umbelliferae* (i.e. *Anthriscus sylvestris*, *Heracleum sphondylium*) and other dicots (*Rumex acetosa*, *Taraxacum officinale*, *Geranium pratense*)

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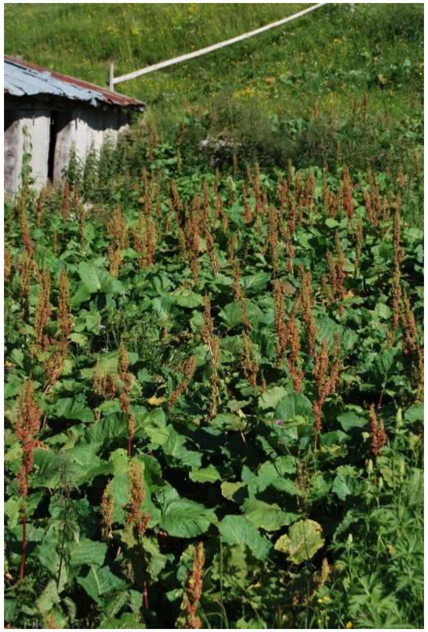
Pasture maintenance

- At least once at the end of the grazing season
- Topping of avoided plant nests; weeds should be controlled as soon as they appear (some of them are indicators of overfertilisation → remove the causes of their occurrence)

Veratrum album

Senecio alpinus (=Senecio cordatus =Jacobaea alpina).



Rumex alpinus

Deschampsia caespitosa

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Effect of pasture-based diet on the quality of milk products vs. diet based on conserved forage and concentrates

Quality trait	*Quality aspects involved*	*Product the trait is relevant to*	*Effect on product*
Oleic acids, PUFA, CLA, Omega-3 PUFA, odd and branched chain FA, vaccenic acid	Nutritional/ technological	Milk, cheese, butter and all fat-containing dairy products	Increase
Omega-6/omega-3 PUFA ratio	Nutritional		Decrease
Oleic/palmitic fatty acid ratio (spreadability index)	Sensory/technological		Increase
Vitamin A and E	Nutritional/technological		Increase, Increase of shelf life
Carotenoids	Sensory/ nutritional/ technological		Increase, Increase of shelf life
Texture	Sensory	Butter and cheese	Increased softness and spreadability
Colour	Sensory	Milk, cheese and butter	More yellow
Flavour/Odour/Taste	Sensory	Milk, cheese and butter	More grassy and flowery aroma, more intense notes
Volatiles compounds	Sensory	Milk and cheese	Increase in odour active compounds

Source: Peratoner et al. 2015

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Effect of pasture-based diet on the quality of meat products vs. diet based on conserved forage and concentrates

Quality trait	*Quality aspects involved*	*Product the trait is relevant to*	*Effect on product*
Omega-3 PUFA, CLA	Nutritional/ technological	Meat	Increase
Carotenoids	Sensory/ nutritional/ technological		Increase, increase of shelf life
Indoles, skatoles	Sensory		Increase
Flavour/Odour/Taste	Sensory		More animal, more grassy, more intense
High standard of animal welfare	Ethical	All	

Source: Peratoner et al. 2015

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Pros and cons of pasture-based grassland production

- Pros
  - reduced production costs
  - reduced labour demand
  - improved animal welfare
  - pastoral landscape (relevant to tourism)
  - high conversion efficiency from forage to food (if plants are grazed at an early phenological stage)
  - Improved nutritional value of products (milk, meat)
- Cons
  - lower per-cow yield and thus reduced revenue (not necessarily reduced income) + increased demand for land availability
  - high demand on management competence

Source: Thomet et al. 2011

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Prerequisites for a successful pasture-based production

- Sufficient land availability
- Sufficient proximity of areas to be grazed to the farm buildings
- Topography suitable for the grazing livestock (species and breed requirements should match the given topography)
- Acceptance for reduced cow performance
- Use of suitable breeds (especially concerning cows)
  - Reduced body weight (important on steep slopes)
  - Ability for high intake of herbage relative to energy demand
  - Ability to maintain body condition on grass diet
  - Reduced requirements for concentrate supplementation
  - High reproductive performance

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Temperate grasslands in Italy

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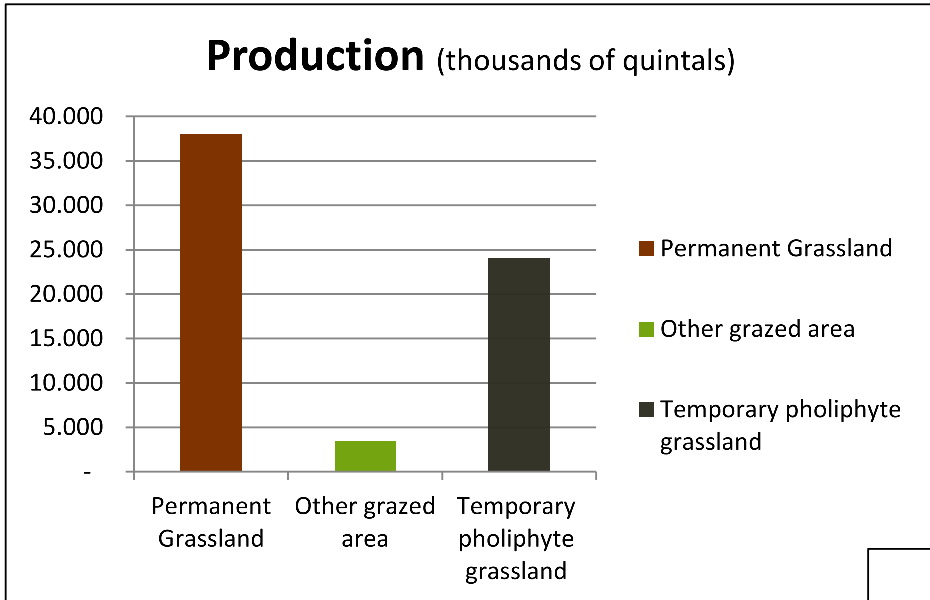

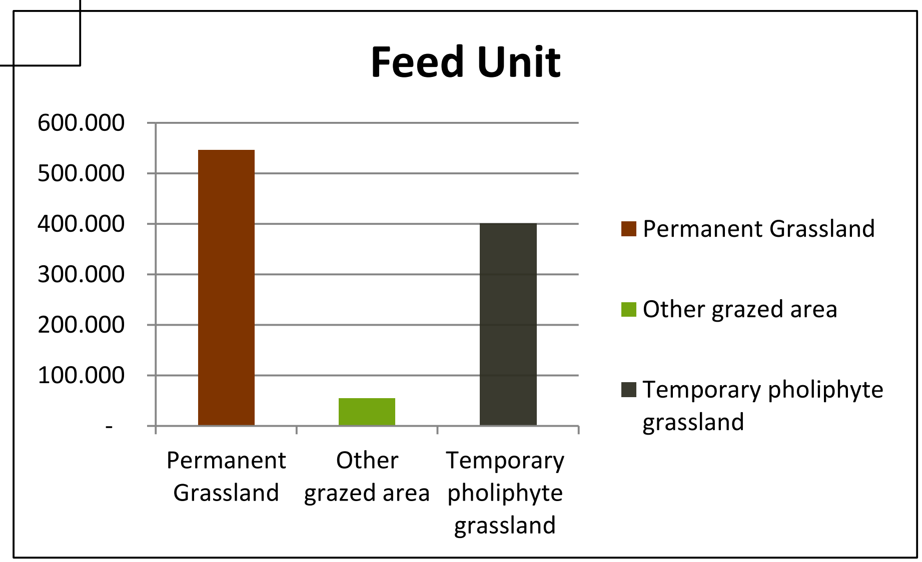

Source: ISTAT,2017

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The **Po Valley** is the most extended area with continental temperate climate in which **permanent grassland** are traditionally large diffuse

Grassland is “permanent" if is not plowed for at least 10 years. Thus, **Permanent grassland** are never alternated with other crops and are managed through **cutting**, **irrigation** (in the flat land) and **fertilization** (Bocci M. *et al*, 2011).

Pieve di Bibbiano, grassland whose existence dates back to about 1300

In the Po Valley 60% of permanent grassland exceed 75 years and only 15% has been sown or renewed over the last 25 years (CRPA, 2007)

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Biodiversity: more than **60 botanical species** have been surveyed on these fields, present significantly and continuously.

IRRIGATION of grassland: traditionally the grassland in the valley are irrigated the first part of summer.

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Temporary grassland enters in a crop rotation: soil's characteristics determine the choice of legumes (pH, lack of limestone and waterlogging), grasses are more conditioned by the climate. Usually < 10 years

Among the **criteria for choosing the varieties** to be combined there is the necessity to have flowering of legumes and grasses in the same time (better feed value and production):

- in mixtures with alfaalfa it is good to use late varieties of *Dactylis glomerata* and *Festuca arundinacea*;
- in mixtures in which the legumes are made of white clover, choose variety of grasses with intermediate precocity;
- when is present *Phleum pratense*, it is necessary to use the most precocious varieties.

Dactylis glomerata *Festuca arundinacea* *Red clover* *White clover*

Source: CRPA, 2014

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Fertilization: both permanent and temporary grassland are fertilized in many cases

The adoption of fertilization management that recovers the uptake of the crop is sufficient to mantain the soil fertility avoidin leaching. An increase fertilization doesn’t increase quality by more than 10 % *(Bonifazzi B,,2009).*

In the permanent grassland, fertilization is an instrument of floristic and productive rebalancing

Grassland can effectively use the manure to maintain fertility, in the temporary grassland are distributed (during plowing and every autumn) even doses of phosphorus and potassium (about 50 kg/ha)

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Renewal of degraded grassland

Important instrument where the fodder crop are of low quality
or weeds have increased dramatically

- ✓ **Rationalizing fertilization**. It is a powerful factor for modification of the grassland composition (grass/legume)
- ✓ **Overseeding**. Useful to thicken the field with the direct sowing of good forage crop; it is applied with the availability of water to ensure germination
- ✓ **Reseeding.** When the degradation is total, the field is completely renewed. After a superficial soil working , a mixture of grass/legume is sown

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Management-Biodiversity

A intensive, management of the grassland, especially characterized by **frequent cutting** ,load to reduce the species and, in the limit cases, leads to "**permanent monoculture**" of Italian rye-grass.
A better management (**< cuts and/or rotational stocking**) increase the biodiversity

In fields with good biodiversity the grasses more represented, in addition to the ryegrass and Poa, are the *Dactylis glomerata*, bromus , festuche, the oats and *Holcus lanatus*.

Are left **non-cutted grassland strips** to increase both vegetal and entomological biodiversity,

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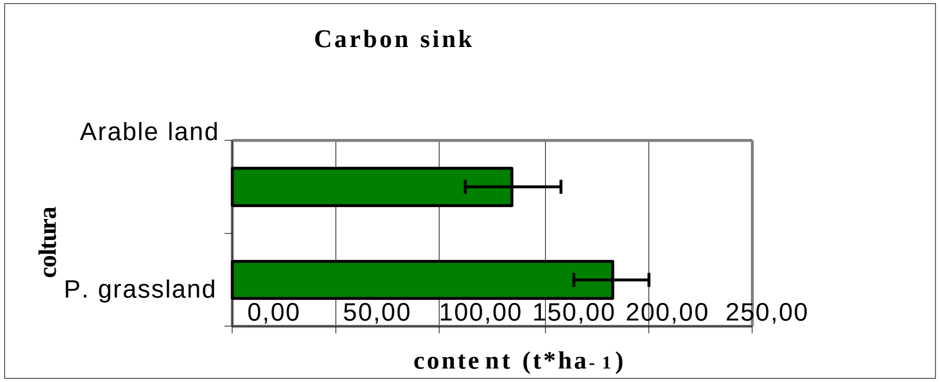
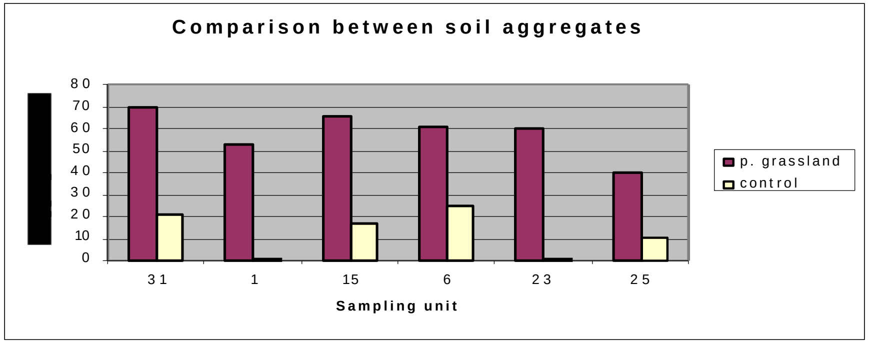
Permanent grassland fixes about **180 tons of carbon per hectare** in the first 50 cm of soil, more then 25% respect to one ha of arable land



Permanent grassland soils have a significantly **higher stability index** than arable land. This can be due to higher presence of organic matter



Source: Parma province, 2005

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Permanent grassland in Italian temperate region are strictly linked with dairy cow breeding of ***Grana Padano*** and ***Parmigiano Reggiano*** chains.

PARMIGIANO REGGIANO

Permanent grassland provide excellent quality forage which responds in a balanced way to the nutritional needs of the livestock, playing an important role in defining the sensorial attributes of Parmigiano-Reggiano (CRPA, 2007).

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Production of grassland in temperate areas

Hay production depends to the seasonal trend and management averaging **10-11.5 tons per hectare from 3-4 cuts** (5 cuts in particularly favorable seasons) of which the first , most abundant, is carried out in the first half of May while the others are carried out at a variable distance of 35/40 days.

The FU contents calculated for the production of grassland are in a range from 0.65 to 0.69 - 0.74 FU/kg of DM (Superchi et al., 2007), up to 0.8 UFL/kg of DM contained in hay (INRA, 2002).

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Thanks to all contributing partners of Inno4Grass

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