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The Grassland Expert Forum

Innovative use of grassland for resource protection

The DAFA Research Strategy

Imprint

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Innovative use of grassland for resource protection
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Content

Foreword



Societal appreciation of grassland as a defining element of our agricultural landscapes has greatly increased in recent years. This is due to wide recognition that grassland provides diverse and relevant benefits to society. The nature and extent of these benefits are largely determined by the management practices applied to grassland. The production of marketable agricultural goods often competes with the delivery of non-market services and benefits such as biodiversity, carbon sequestration, hydrological benefits, landscape-related aesthetic effects and the cultural contribution of grassland. The challenge is to develop grasslands so that they address varied expectations simultaneously. Trade-offs and conflicts between objectives tend to increase with specialisation and intensification of agricultural production systems. There is a lack of knowledge of how to address these conflicts and provide solutions that reduce them. This Strategy identifies research priorities to address these deficits identified against a background of limited resources.

The DAFA Grassland Expert Forum includes representatives of different actors in society that have an interest in grassland. In addition to scientists from various disciplines and institutions, these include the representatives of the farming sectors concerned and the pre-farm and post-farm economic sectors, agencies involved in natural and environmental protection, administration and policy. This research strategy has been developed in a broad discussion process aimed at making grassland management more sustainable. If current farming systems do not meet the range of societal expectations regarding ecosystem services, then appropriate innovations in grassland use are needed. Therefore, the DAFA Research Strategy focuses on the limits of today‘s farming systems and the potential for the development and introduction of appropriate innovations. This is obviously a Herculean task that depends on a paradigm shift in the perception of the potential of grassland for agricultural production. Ultimately, it comes down to the preservation and promotion of the value of grassland in our agricultural landscape for society. This can be achieved only through collaboration of the various parts of society with agriculture. Through innovations in management, the use of grassland has to be made more attractive.

This research strategy picks up on this perspective; it analyses the current trends in grassland use and the consequences for grassland research and development. It draws particular attention to the need to address challenges in both the content of research and structural challenges in research systems in Germany. It seeks to lead towards high-performance, system-oriented grassland research that has a high profile nationally and internationally and that is characterised by interdisciplinary and transdisciplinary activity.

Summary

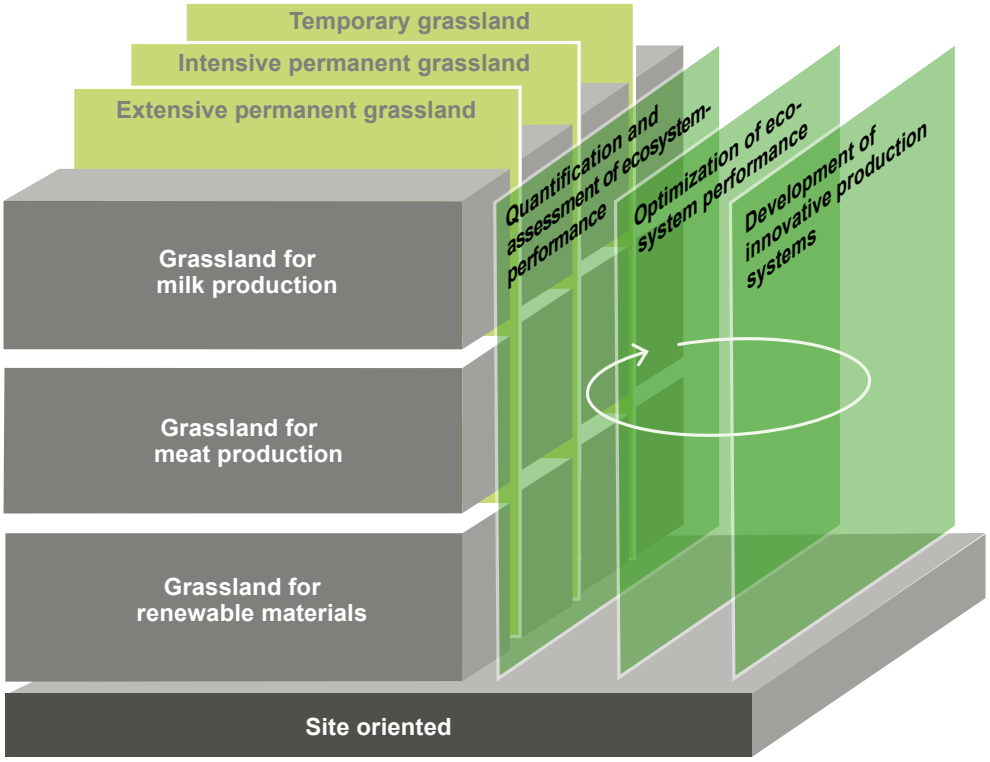
This Strategy supports reorientation of research so that economic performance and the delivery of ecosystem services, such as biodiversity or water regulation, are combined.

1 What's it all about?

Grassland is traditionally farmed for the production of fodder and biomass. However, grassland also provides a variety of other ecosystem services. Usually, it is not possible to maximise all these services simultaneously, there are trade-offs. The range of the various services and the extent of trade-offs among them depends on the type and intensity of grassland farming. Efforts to preserve and enhance ecosystem services, develop greater awareness in society and reduce trade-offs must therefore start with the agricultural production systems themselves. Thus, grassland farming must be aligned with societal expectations, be resource efficient, and environmentally sound. By securing the provision of a range of ecosystem services, the overall value of grassland to society can be increased.

With this strategy the DAFA Grassland Expert Forum aims to identify and develop the innovative value-added potential of grassland, which includes both the production of agricultural products and the supply of other ecosystem services that have extensive societal benefits. Increased research initiatives are needed to develop future-oriented agricultural production systems that provide these ecosystem services. To this end, the causal relationships between the production system and ecosystem services must be analysed in order to comprehensively evaluate the performance of the systems. This is the basis for communicating about the societal value of grassland.

Figure 1: Conceptual framework of the DAFA Grassland Research Strategy



2 Problem definition

The agricultural role of grassland has been declining for decades compared with arable land. This was especially true in intensive production systems like dairy farming, where there has been increasing reliance on concentrate feed and high-yielding silage maize, which has benefited from intense technical development, rather than grass. Meanwhile, values of intensively managed grassland are increasing due to the increasing global demand for agricultural products and the use of agricultural land for bioenergy promoted by the Renewable Energy Law. This increase in land value increases the pressure to realise high yields of high quality fodder.

In contrast, the profitability of agricultural production on extensive semi-natural grassland, which is particularly valuable from the perspective of nature and environmental protection, is rarely sufficient to secure the future of this form of land use. The reduction in the attractiveness of extensive permanent grassland for agricultural production purposes compared with arable use is reinforced by environmental regulations and zoning of land for environmental purposes. The management of extensive permanent grassland in particular was and is economically unattractive for many farmers with the result that tillable grassland has often been transformed into arable land. Non-tillable grassland has been afforested or taken out of production. Cessation of agricultural production leads to the growth of scrub and in the long term a loss of grassland and its characteristic ecosystem services. Innovative approaches to the sustainable use of grassland are therefore essential.

The future of grassland in Germany depends on the value grassland can generate. Further increases in yield and forage quality using resource-efficient techniques are desirable on productive sites. At the same time, this production must secure and even increase the provision of other ecosystem services. This applies also to extensive permanent grassland, which would benefit from better utilisation and exploitation of unused production potential. Depending on the grassland type and location, the priorities for the expected outputs from grassland will thus vary considerably. The economic opportunities for grassland have improved significantly due to increased global demand for high-quality and sustainably produced foods, the increasing competition for land and increased prices for fodder, substrate for biogas, and food. Innovative production systems that reduce the outlined trade-offs are therefore more economically attractive and can make an important contribution to the global provision of food supplies

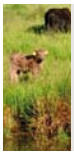
3 Requirements to research

For the development of innovative production systems, research is required to provide comprehensive solutions that cannot be found using isolated and disciplinary research focused on single questions. A system-oriented collaborative effort that combines different disciplines in a joint research effort framed by value chains is needed. This needs to involve the target groups and institutions in a transdisciplinary way. Research funding organisations need to establish appropriately designed new funding instruments for addressing these challenges.

4 Research needs

The DAFA Grassland Expert Forum sees need for action in several areas. The aim of new research approaches must be to carve out the currently unused potential of grassland and to combine the results in future-oriented utilisation concepts. New utilisation concepts and production processes need comprehensive evaluation. Thus, ecosystem services other than biomass production must be identified and quantified site-specifically. The marketing potential of grassland products needs to be considered. For prompt introduction into agricultural practice and to clarify short- and medium-term effects, economic and policy assessments are required. The extension system must be involved at an early stage in order to successfully transfer knowledge into practice. The Expert Forum defines priority research fields and innovation needs in production processes along the major value-added products from grassland as follows:

Protein from grassland
Innovation in milk production



Meat better from grassland
Innovation in meat production

Grassland: a new source of raw materials
Innovation for use as a renewable resource

5 Requirements to research funding

To achieve the research objectives and implement results in practice, the necessary structural conditions must be created. Research funding should give priority to interdisciplinary and transdisciplinary activity. Through a strong interdisciplinary approach, the system suitability of innovations shall be supported. The early involvement of research users in the research ensures the relevance and feasibility of innovations for practice.

1 Introduction – why a research strategy for grassland?

Grassland provides important services and is a major land use type in Germany. However, the economic returns to using grassland have decreased due to changing circumstances and research on grassland production has declined. The DAFA Research Strategy aims to boost innovation and restore the appeal of grassland for agricultural production and the provision of other services.

Grassland accounts for about 35% of the utilised agricultural area (UAA) in Europe, or about 8% of the total land area.[1] It thus represents an important agricultural resource. In Germany, 28%[2] of the UAA is grassland (corresponding to 14% of total land area). The keeping of ruminants and horses is usually linked to grassland. The grass is either grazed or cut for forage that is fed directly or conserved for winter-feeding. In addition to this agricultural production, grassland provides essential functions and delivers important ecosystem services. This is mainly through the provision of environmental goods that can only be delivered by grassland and that have a high social as well as ecological significance. These are non-market goods demanded by society such as biodiversity, soil carbon sequestration, regulation of water, protection of soil from erosion, and the aesthetic value of grassland in landscapes.

The production potential and the possible ecosystem service provision of grassland are so far not fully exploited. Thus, there are large regional differences within Germany in how grassland is used for fodder. While milk production and thus also the economic importance of grassland in mountain regions is commonly in decline, the demand for energy and protein-rich forage has increased in intensive livestock regions in the northwest and southeast of Germany. However, if an increasing part of the fodder is produced on arable land, the already tense competition for arable land is further intensified. At the same time, there is increasing pressure to intensify grassland management, to convert grassland to cropland or to take grassland out of production. Through these three processes, important ecosystem services of grassland are changed, compromised or even lost.[3]

The driver behind these developments in agricultural practices is, among other things, the provision and use of technical progress in other areas of agriculture, such as in animal breeding or husbandry or in breeding and cultivation of arable crops, which is far more advanced than in grassland management. This has reduced the competitiveness of grassland. This deficit in grassland research for the development of modern production systems is also reflected in the research and extension infrastructure. Research capability relevant to agricultural production on grassland has been significantly reduced in the last two decades, and appropriate extension expertise for the agricultural practice is often no longer existent. The evidently eroded capacity in grassland research, innovation and knowledge transfer must be urgently restored through appropriate systems-oriented approaches. This is the challenge addressed by the DAFA Grassland Research Strategy. It presents perspectives and approaches to making grassland research in Germany more effective.

[1] Smit, H.J., Metzger, M.J. and Ewert, F., 2008: Spatial distribution of grassland productivity and land use in Europe. Agricultural Systems 98, 208-219.

[2] EUROSTAT 2013

[3] Cf. Gerowitt, B., Schröder, S., Dempfle, L., Engels, E.-M., Engels, J., Feindt, P.H., Graner, A., Hamm, U., Heißenhuber, A., Schulte-Coerne, H., Wolters, V., Wissenschaftlicher Beirat für Biodiversität und Genetische Ressourcen beim BMELV, 2013: Biodiversität im Grünland – unverzichtbar für Landwirtschaft und Gesellschaft. Stellungnahme des Wissenschaftlichen Beirats für Biodiversität und Genetische Ressourcen beim Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz, 20 S.
BfN 2014: Grünland-Report – Alles im Grünen Bereich? Stellungnahme des BfN, 34 S.

2 Grassland, production systems, ecosystem performance – terms and definitions

Grassland flora consists mainly of grasses, herbs and legumes. It must be regularly defoliated. Permanent grassland is such vegetation that has been undisturbed by soil tillage for at least five years. Grassland-based farming produces agricultural goods by grazing or cutting. The term ecosystem service refers to all the benefits provided to humans by ecosystems. This may include the production of biomass, the conservation of biodiversity, or recreation benefits.

What is grassland?

Grassland is defined as a land use type where the vegetation is dominated by herbaceous perennial plants, especially grasses, and where woody plants such as trees and shrubs are largely absent. Grassland vegetation typical presents itself under central European conditions where tillage is not conducted for several years and where the grassland sod is regularly defoliated. Grassland is extremely diverse. Depending on the age of the sward, a distinction can be made between permanent grassland and temporary grassland.

The diversity of permanent grassland in Central Europe is due to the variety of site conditions and the range of agricultural uses and management approaches. Historically, grassland is not sown and the resulting grassland-typical vegetation thus contains many wild plants that occur naturally in the respective locations. This ‚naturalness' of the vegetation is the basis of the diversity of higher plant species in permanent grassland in Central Europe, which is more than three-fold that found on arable land. In addition, these wild plants are relatives of crop species and thus an important gene pool for present and future breeding efforts.

With the intensification of grassland management since the 1950s, a significant proportion of grassland has been sown with improved cultivars. Combined with improvements in production technology such as an increase in fertilisation and increased frequency of cutting or grazing, this has resulted in significantly increasing economic returns and improved forage quality. However, the associated loss of biodiversity cannot only be attributed to these

Intensively managed meadow: a species-poor sward develops where an intensive cutting regime with 4 to 5 harvests per year is used, which is dominated by perennial ryegrass under favourable conditions.

Tall oat-grass meadows: species-rich hay meadows, traditionally under extensive management with moderate nutrient supply.

Mat grass meadows: nutrient-poor meadows on acid soils (here with flowering spignel). These grasslands do not have as many colourful flowers as other extensive meadows.

Species-rich moist meadow with pink flowering meadow bistort: moist and wetland meadows have declined in Central Europe due to drainage and melioration.

changes. The improvement of grassland soils and the resulting loss in variation in local conditions also played an important role.

In European Union policy, the term **permanent grassland** applies to land that is sown or is naturally self-seeded to grow grasses or other herbaceous forage plants and that has not been tilled for at least five years as part of a cropping sequence. In the new Common Agricultural Policy, this definition also allows Member States to categorise other traditional regional grassland sites as permanent grassland and enable the application of the relevant regulations to them.[4]

In contrast, **temporary grassland** includes perennial forage stands including grasses, clover and alfalfa, as well as grassland that is regularly reseeded to regenerate grassland. The use of temporary grassland is limited to a maximum period of five years through the effects of the cross-compliance rules and the new ‘Greening‘ measures in the current EU agricultural policy.[5]

The DAFA Grassland Expert Forum addresses all types of grassland: permanent and temporary, including perennial forage cropping (grass and clover mixtures). With permanent grassland, two extremes can be distinguished, i) intensively used highly productive permanent grassland and ii) permanent grassland managed extensively for agricultural purposes. Extensive permanent grassland includes species-rich complexes managed within or outside a special regulatory framework as well as grassland with a high conservation value. Maize and other arable crops used for forage are not considered here. This broad interpretation

[4] Verordnung des Europäischen Parlaments und des Rates Nr. 1307/2013 vom 17.12.2013 mit Vorschriften über Direktzahlungen an Inhaber landwirtschaftlicher Betriebe im Rahmen von Stützungsregelungen der Gemeinsamen Agrarpolitik und zur Aufhebung der Verordnung (EG) Nr. 637/2008 des Rates und der Verordnung (EG) Nr. 73/2009, Art. 4 Abs. 1

[5] http://www.landwirtschaftskammer.de/foerderung/hinweise/kulissen.htm#Welches

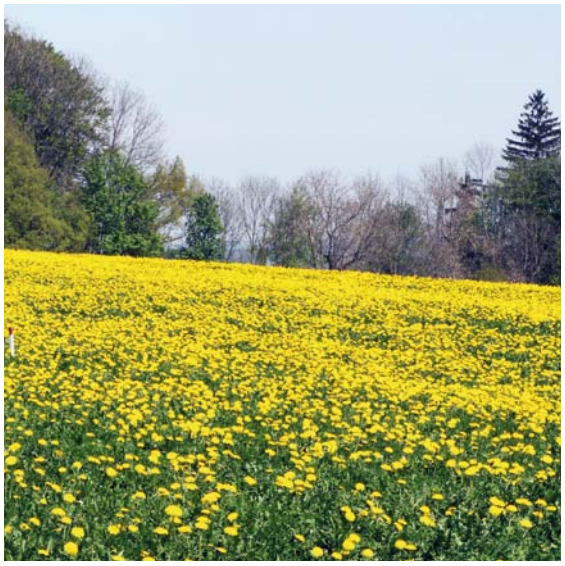
of the term grassland is due to the focus on the excellence of agricultural grassland use and therefore aspects like the pre-crop effect of grasses and clover swards in cropping systems are to be appropriately considered.

What are grassland production systems?

Grassland-based production systems deliver a notable quantity of marketable agricultural goods. For livestock, grassland makes an important contribution to feed energy and nutrient supply. Grassland-based livestock production can range from very extensive to very intensive. In intensive systems such as for milk production, the feed energy and protein input from grassland is sufficient for the production of 10,000 kg milk per ha and year. On well-suited locations and with optimised management, an area-related performance of up to 13,000 kg of milk per hectare exclusively from grass has been measured.[6] Grassland can surpass many arable crops in terms of area-related economic performance. In extensive systems, such as the suckler-based beef production, area-related economic output is usually nowhere near that of arable crops. However, individual animal performance, for example live-weight gains of growing heifers for the restocking of dairy herds, can be similar to that of intensive systems.

Grassland is to date a small but increasingly important supplier of raw materials for energy production. It is also a genetic resource and provides special services for relaxation and leisure (including leisure horses). All these are

Foxtail grass meadows: moist sites – 2 to 4 cuts per year depending on the intensity of use.



Meadows with dandelion: they develop on well-fertilised locations with mineral soils rich in organic matter and are characterised by reduced yields of grasses with high fodder value.

[6] T Cleven, M., Verhoeven, A., Pries, M., Berendonk, C., Wrage-Mönnig, N., 2015: Wieviel Milch bringt die Weide? Vergleich zweier Berechnungsmethoden. In: Messner, J., Elsäßer, M. (Hrsg.) 59. Jahrestagung der Arbeitsgemeinschaft Grünland und Futterbau, Aulendorf, Tagungsband 193-195.
Pinxterhuis J.B., Beare M.H., Edwards G.R., Collins R.P., Dillon P., Oenema J., 2015: Eco-efficient pasture based dairy farm systems: a comparison of New Zealand, The Netherlands and Ireland. Grassland Science in Europe 20, 349-366.
Pries, M., Berendonk, C., Verhoeven, A., Hoffmanns, C., Cleven, M., 2015: Kurzrasenweide ganztags oder halbtags mit Kühen nutzen? In: 15. Forum angewandte Forschung in der Rinder- und Schweinefütterung, Fulda, 14./15.04.2015

Yellow oat-grass meadows: traditionally extensively used species-rich upland hay meadows.

Legumes such as white clover improve the sward and reduce the need for nitrogen fertiliser.

based on utilisation of primary production, i.e. the production of aboveground plant biomass. The sward is used differently depending on the system. A distinction is made between cutting and grazing systems. Within each system, management may vary with regard to the frequency of cuts, the harvest technique or grazing management, and may change on one sward throughout the year (mown pastures). The harvesting process may be followed by the use of preservation techniques and ultimately the feeding of the harvested material as green forage, silage and hay, use as a renewable resource or as bedding (scarcely used today however). Each of these processes in turn depends on various production factors. These include hay drying, the use of silage additives, or mashing before pelleting. These various process chains produce a range of different products from grassland.

What are ecosystem services?

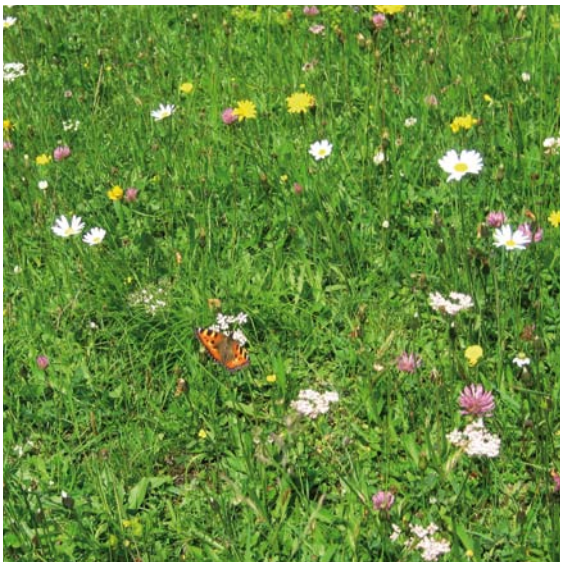
Ecosystem services are the benefits that humans gain from the functioning of ecosystems. Ecosystems provide goods and services that support human well-being through direct or indirect economic, material, health or mental benefits.[7] Provisioning goods and services are directly used by man for the supply of food and other raw materials. Provisioning services also include renewable resources like drinking water supplies. Regulating goods and services form another category. These are generally of indirect benefit to humans, but guarantee e.g. the functioning of ecosystems. They include processes that contribute to the regulation of water, prevention of soil degradation, reduction

[7] Daily, G. C. 1997. Nature's services: societal dependence on natural ecosystems. Island Press.

of greenhouse gas emissions or less nutrient losses. Even biological benefits, such as the conservation of biodiversity and pollination services can be assigned to this category. A third category is cultural goods and services, for example those linked to the aesthetic appreciation and recreational value of landscapes.[8] Furthermore, these services include those forming people's regional identity (e.g. alpine transhumance systems). These cultural services are perceived directly by people and represent a critical factor for the acceptance and thus for the long-term success of innovations in grassland management.

Compared to arable land, grassland has a greater potential for providing ecosystem services next to the production of agricultural goods. The range of ecosystem services cannot be provided simultaneously and to the same extent. The increase in the provisioning of one special ecosystem service often leads to reduction of other services, resulting in trade-offs. Strong trade-offs among the various services from grassland are often the cause of conflicts among stakeholders or societal groups that expect or demand specific benefits from grassland.

Biodiversity and insects: examples of ecosystem service provision in grassland (biomass, biodiversity, habitat for pollinators).



[8] Cf. Millennium Ecosystem Assessment, 2005: Ecosystems and Human Well-Being: Synthesis. Island Press, Washington, D.C., pp. 1-137
Additionally cf.: Burkhard, B., Groot, R. de, Costanza, R., Seppelt, R., Jörgensen, S.E. & Potschin, M., 2012: Solutions for sustaining natural capital and ecosystem services. Ecological Indicators, 21, 1-6, doi:10.1016/j.ecolind.2012.03.008
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UK National Ecosystem Assessment, 2012: Ecosystem Services,
http://uknea.unep-wcmc.org/EcosystemAssessmentConcepts/EcosystemServices/tabid/103/Default.aspx (Date: 11.04.2012)

3 Trends in grassland-based production systems

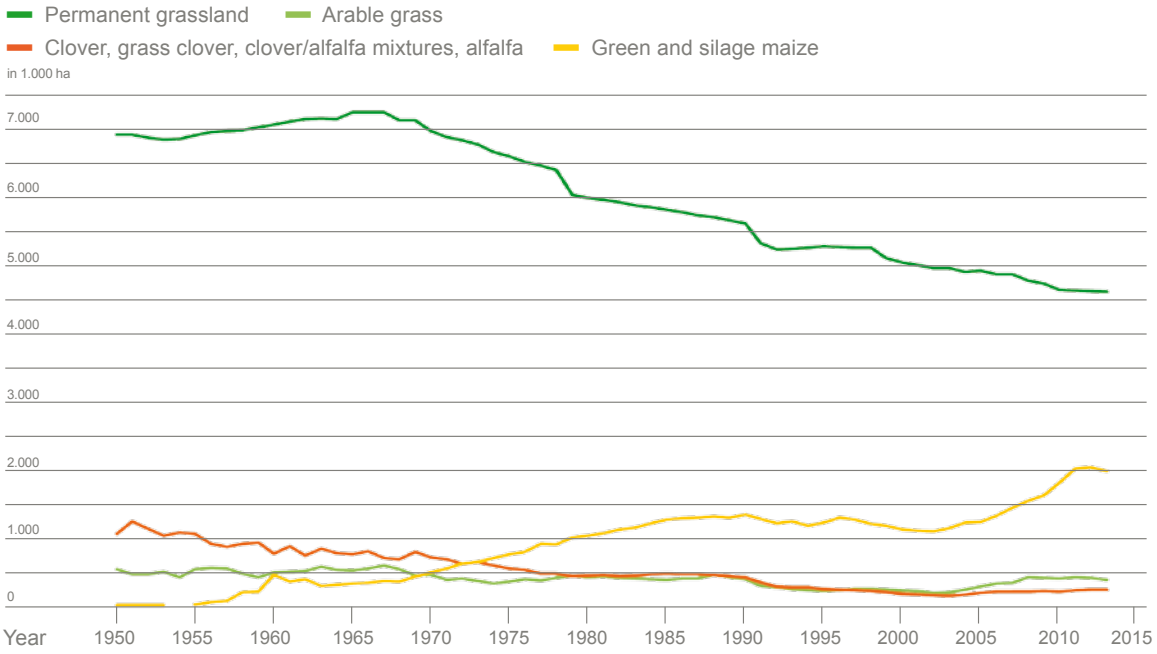
The grassland area in Germany has dropped in the last 50 years by about 30% because the productivity of cattle has increased and more silage maize and concentrate feed is used. The use of grassland to keep sheep and horses is limited to a relatively small proportion of grassland. Energy and material use is still under-developed.

Trends in land use for forage production

The area and yield of forage crops are subject to continuous change. Considering all crop types that serve forage production, i.e. grassland and forage crops, there has been a decline in the area cultivated for forage production (Figure 2). This decrease is mainly due to a strong reduction of cattle numbers associated with improvements in animal performance. The increase in the maize acreage is due only to the increased production of maize as a substrate for biogas production since 2002.

Since the early 1990s, the economic competitiveness of grassland has been reduced by the changes in the European and German agricultural policy. The so-called MacSharry reform led to area-related payment rights for arable land but not for grassland. This was in effect a subsidy for arable cropping including arable cropping for forage, which reduced the cost of silage maize compared to grassland on a feed energy basis by approximately 30%. The consequences varied among regions. In areas dominated by land unsuitable for arable cropping, grassland production was extensified, facilitated by falling livestock populations due to the cap on milk production under the milk quota system. This was reinforced often by publicly funded milk extensification programmes such as KULAP, MEKA etc. Because of site-related disadvantages, forage yield and quality (energy

Figure 2: Grassland and forage crop production in Germany



Source: Statistisches Bundesamt: Lange Reihe der Landwirtschaftsstatistik von 1938-1996 for the current Federal area, Fachserie 3 Reihe 3.1.2 (various editions and annual reports) and Genesis Online Databank (Code 41241).

and protein density) in these regions is typically low. As a result, milk or meat yields on this grassland are significantly below those of intensively managed grassland, whereas ecosystem service provision regarding the conservation of biodiversity and the landscape aesthetic value in these areas is high. In regions where land can be tilled, much has been converted. However, changing land use from grassland to arable cropping is now regulated at regional, national and European level (conversion bans) and thus the permanent grassland share of the agricultural area is largely fixed independent of its value in terms of the provision of ecosystem services. Likewise, permanent grassland is equal to arable land in terms of direct payment entitlements. This increases the economic value of intensive grassland.

Short-lawn pasture: intensive form of grassland management using dairy cows.

Production trends

Beef and dairy

Grassland can deliver good quality forage that can supply large ruminants with sufficient energy and protein as well as nutrients and active ingredients. Grass is a complete food for these animals. This applies primarily to extensive livestock farming methods such as the suckler cow, sheep or extensive equine management.

However, also the higher nutrient and energy needs of dairy cows and growing cattle can be largely covered by grass. Grassland-based milk production may generate high economic return on a per hectare basis under favourable conditions. As shown by data from farms feeding only through grazing, grazing cows can produce about 25 kilograms of milk per cow per day from grass without feed supplementation. Grazed grass is the most cost-effective roughage component assessed on the basis of feed energy (full cost 0.1 - 0.2 € / 10 MJ NEI[9]). However, grazing of dairy cows has declined for years and further decline is expected as herd sizes increase. Site factors, in particular water supply and temperature extremes mean that grazing alone cannot be relied on for continuous fodder production and animal welfare in all regions of Germany. Systems that are not fully dependent on grazing and use supplementary feeding are required. This adds expense because two feeding and husbandry systems are needed: grazing and housed production. Growing herd sizes increase the necessary grazing area and subsequently the distance from the milking parlour to grazing areas

[9] Energy needs per 1 kg of milk in megajoule Net Energy of Lactation (NEI).

Traditionally, dairy cows were kept over day on continuous pastures near the farmyard.

quickly becomes a limiting factor. Especially with larger herds, the grazing management requirements increase significantly compared with housed systems.

Despite the generally high production potential of grassland for ruminants, milk is in practice increasingly produced from other feed sources in addition to grass. Agricultural extension service surveys show that even in grassland regions that are increasingly important for milk production in Germany[10], the proportion of grassland fodder in the energy supply of cows is often less than 40%. Therefore, 60% and more of the feed energy demand is met by supplementary concentrate feeding and by high-value forages from arable land (maize). In addition to energy needs, also the protein needs are increasingly met by concentrate feeding (including rapeseed and soybean meal) because of the high protein supplementation needed in maize-based rations and the increasing protein demands that go with increased milk yields per cow.

It is foreseeable that the trend towards higher individual animal performance (and thus higher concentrate feed use) and larger herds (and thus reduced grazing) will increase with the abolition of milk quotas in 2015. In these circumstances, grassland will be increasingly used as a source of grass silage for all-year-round housed feeding. The demands on the energy content and the protein value of the harvested grass will continue to rise along with the level of performance of the individual animals. With regard to forage production and preservation from grassland, there are development needs in particular in plant breeding (yield, quality), fodder preservation and the fodder processing chain.

Nevertheless, this development focussing on grassland as a source of mechanically harvested forage must be considered critically for several reasons (see also DAFA Livestock Expert Forum). Dependence on year-round housing systems with maximum animal performance reduce grazing and risks conflicts with regard to animal welfare objectives and societal acceptance. These systems are associated with relatively short cow lifespans and high replacement rates that in turn lead to high costs and eco-efficiency challenges. An increased use of concentrate feed (e.g. soy) causes indirect land use changes in the producing countries (South America) and increases the life-cycle emissions per unit product of milk in Germany.[11] Finally, these highly intensive milk production systems are

[10] Lassen B, Isermeyer F, Friedrich C (2008) Milchproduktion im Übergang – eine Analyse von regionalen Potenzialen und Gestaltungsspielräumen. Braunschweig: Johann Heinrich von Thünen-Institut, Arbeitsberichte vTI-Agrarökonomie 09/2008 http://literatur.ti.bund.de/digbib_extern/bitv/dk040798.pdf

[11] Taube, F., Gierus, M., Herrmann, A., Loges, R. and P. Schönbach (2014): Grassland and Globalization - Challenges for Northwest European Grass and Forage Research. Grass and Forage Science, 69 (1). 2-16. DOI: 10.1111/gfs.12043

Extensive grassland can be used for sucker cows.

associated with high energy use, which increases the impact of energy prices on the economic performance. Pasture-based milk production with average animal performance levels is an alternative. Compared to year-round housing, energy use can be significantly reduced and the protein-rich supplementary feeding avoided completely, making a significant contribution to reducing reliance on imported feed. The extent to which biodiverse swards can be used to improve animal health and performance are issues on which considerable further research is necessary.[12]

There are two broad categories of beef production activity: suckler cow keeping and beef cattle fattening. The purpose of suckler cow keeping is the production of calves that remain with their mothers until they are 6 to 9 months old. They first feed exclusively on their mothers' milk, later partially. The suckler production cycle ends with weaning. The weaned calf might be fattened on the same farm or sold to farms specialised in fattening. Weanlings or yearlings are only rarely slaughtered, so that the weaned calf is the foundation of beef production, but not beef production itself. Suckler cows accounted for 15 %[13] of all cows in 2013 so that most beef production in Germany is based on calves from the dairy herd. However, there are differences between regions. Due to the small number of dairy cows in eastern Germany, suckler cows are important for the maintenance of grassland there.

Typically, suckler cows graze at least during the grass-growing season. In many farms, the animals are housed in winter and fed with silage, hay and purchased feed. On some sites with suitable mineral soils, however, animals are kept outside also in winter with supplementary feeding.

In dairy production, pastures are often used for raising young female stock that have a lower feed requirement than lactating animals. However, these animals are rarely fattened on pasture.

The use of pastures for fattening is relatively rare in Germany.[14] Fattening on pasture uses mostly heifers and steers because of the difficulties of managing grazing bulls. The contribution of steers to the beef production in Germany is only about 1%. However, it can be assumed that (partly) grazing heifers contribute significantly to organic beef production. Since the proportion of all beef that is organic

[12] Cf. Gerowitt, B., Schröder, S., Dempfle, L., Engels, E.-M., Engels, J., Feindt, P.H., Graner, A., Hamm, U., Heißenhuber, A., Schulte-Coerne, H., Wolters, V., Wissenschaftlicher Beirat für Biodiversität und Genetische Ressourcen beim BMELV, 2013: Biodiversität im Grünland – unverzichtbar für Landwirtschaft und Gesellschaft. Stellungnahme des Wissenschaftlichen Beirats für Biodiversität und Genetische Ressourcen beim Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz, 20 S.

[13] Destatis (2012) Statistisches Bundesamt: Land- & Forstwirtschaft, Fischerei. 2014, www.destatis.de

[14] Deblitz, C., Brömmer, J., Brüggemann, D. (2008): Beef production in Germany - production systems and their spatial distribution. In: Landbauforschung 1/2 2008 (58), S. 29-44. http://www.agribenchmark.org/fileadmin/Dateiablage/B-Beef-and-Sheep/Misc/lbf_2008_vol58_1_2.pdf

has remained below 3% for years, it can be assumed that also the use of grassland by this type of production has not increased.

The role of grassland in cattle fattening is mainly limited to the production of grass silage and to a much lesser extent hay. Both feeds are primarily used to increase the roughage portion of the ration to maintain rumen function. To a lesser extent, they are also fed to cattle in specialised systems such as organic or for special products (e.g. hay milk cheese). The proportion of these fodders generally does not exceed 30% for silage and 5% for hay in the total ration, which otherwise is primarily based on corn silage and concentrated feed.

Apart from location, the role of grass in feeding is generally small and depends on the age of the animal (being higher for young cattle than young calves, weanlings and finishers), the level of performance required, farm operational considerations, and marketing concepts.[15]

In dairy as well as beef production, production improvements have been accompanied with a reduction in diversity of animal genetic resources. While earlier grassland production systems were based on locally adapted breeds, the increasingly intensive housed production has led to dependence on fewer high-performance breeds. On extensive sites, traditional adapted breeds of cattle have been replaced by imported robust breeds.[16] Interest in public policy and in society in the protection and sustainable use of local endangered breeds has only recently emerged and there have been successes with the management of grassland with traditional local cattle breeds. In addition, the increasing demand of citizens for a regional identity is met amongst other things by the presence of regional breeds on grassland.

Sheep permit the productive use of remote sites, as here on the Schwäbische Alb, fragile sites with low tolerance of treading (e.g. dykes) as well as species-rich swards.

Sheep production

Sheep farming is mainly practiced on grassland high in maintenance requirements (e.g. dykes, nature reserves) and often less productive. With just over one million ewes[17] with offspring, the grassland area required is up to 200,000 ha. Sheep therefore play a minor role in grassland farming. However, sheep grazing plays an ecologically very valuable role in maintaining extensive grassland areas and coastal defences (dyke maintenance).

[15] Deblitz, C., Brömmer, J., Brüggemann, D. (2008): a.a.O.

[16] Bundesministerium für Ernährung und Landwirtschaft: Nationales Fachprogramm zur Erhaltung und nachhaltigen Nutzung tiergenetischer Ressourcen in Deutschland, 2008

[17] Destatis (2014) Statistisches Bundesamt: Land- & Forstwirtschaft, Fischerei. 2014, Fachserie: Viehbestand und tierische Erzeugung, Genesis-Online-Datenbank (Code 41311)

In some regions, grassland is in demand for sport and leisure horses. Horses can effectively use structurally rich grassland.

Grassland biomass can be stored as silage and used for energy.

Equine husbandry

Horses are relevant to the use of grassland, especially to structurally complex fodder of diverse swards. There are about 1.1 million horses in Germany[18] that are used mainly for leisure and sports. Around half are kept on farms.[19] For adequate animal welfare, horses require about 0.5 ha grassland per animal.[20] The Chamber of Agriculture North Rhine-Westphalia recommends 1 ha per large horse.[21] Overall, this equates to 500,000 to 1 million ha of grassland needed and therefore horses represent an important user of the approximately 4.6 million hectares of land under permanent pasture in Germany. In some areas, small or dispersed grassland sites are kept in use and protected from succession. Near metropoles, horses can contribute significantly to grassland use and occupy large contiguous areas that determine the perception of grassland in these regions.

Energy production

The industrial material use of grass has not gone beyond the research stage and it is still not significant in economic terms. In contrast, grass swards play an important role in supplying substrate for biogas. However, the combustion of hay as well as new procedures for thermochemical gasification is only a marginal activity and is only relevant at the research level.

[18] IPSOS (2002): Marktanalyse Pferdesportler in Deutschland, Studie im Auftrag der FN, Warendorf.

[19] Gemäß Statistischem Bundesamt, Genesis-Online-Datenbank, Tabelle 41311 wurden bei der letzten detaillierten Erhebung 2007 insgesamt knapp 542.000 Pferde auf landwirtschaftlichen Betrieben gehalten. Laut mündlicher Auskunft vom 25.07.2013 sind darin auch als Pensionspferde gehaltene Tiere auf landwirtschaftlichen Betrieben über 2 ha LF enthalten.

[20] Niedersächsisches Ministerium für Ernährung, Landwirtschaft und Forsten (1999): Empfehlungen zur Freilandhaltung von Pferden, http://www.paktev.de/artikel/233d.pdf.

[21] http://www.landwirtschaftskammer.de/landwirtschaft/tierproduktion/pferdehaltung/betrieb/winterweide.htm

Many farmers are taking an integrated approach with e.g. the first and second cuts used for livestock and subsequent cuts used for biogas.[22] It is therefore difficult to estimate the extent of the grassland area used for energy purposes.

Grass contributes to substrate in 30-40% of biogas plants.[23] According to the DLG, grass accounts for on average 8% of substrate of biogas plants on a weight basis.[24] However, there are large uncertainties with these data. The German Biomass Research Centre (DBFZ) estimated that grass silage and biomass from landscape management accounted for 12% and 2% of substrate in 2013, respectively.[25] In organic farming, grass silage and clover/grass leys account for up to 31% of substrate[26] with an average of 21% from clover/grass and grassland silage.[27] Where manure is used, the energy is a residue of feeding and therefore indirectly also from grass.

Biogas plants are distributed unevenly in Germany. The largest capacity and number of installations can be found in Lower Saxony, Bavaria and Baden-Württemberg.[28] Also within federal states, such as Lower Saxony, the distribution varies among the counties.[29] The amendment of the Renewable Energy Sources Act (EEG) has meant that the profitability of new biogas investment has been reduced and the construction of new plants has declined sharply. The decline in the attractiveness of biogas production does not only apply to grassland use.

[22] DLG 2012: DLG-Merkblatt 386: Biogas aus Gras – Wie Grünlandaufwüchse zur Energieerzeugung beitragen können, S. 5
[23] DLG 2012: a.a.O., S. 4
[24] DLG 2012: a.a.O., S. 5
[25] DBFZ 2014: DBFZ Deutsches Biomasseforschungszentrum, Daniela Thrän (DBFZ/UFZ), Alexander Krautz, Mattes Scheftelowitz, Volker Lenz, Jan Liebetrau, Jaqueline Daniel-Gromke, Martin Zeymer, Michael Nelles: Auswirkungen der gegenwärtig diskutierten Novellie-rungsvorschläge für das EEG-2014 Hintergrundpapier – überarbeitet am 31.03.2014, 12 S.
[26] Anspach, Victor, Siegmeier, Torsten, Möller, Detlev 2010: Biogaserzeugung im Ökologischen Landbau: Strukturen und Perspektiven, kassel university press GmbH, Kassel, S. 37
[27] Anspach, Victor, Siegmeier, Torsten, Möller, Detlev 2010: Biogaserzeugung im Ökologischen Landbau: Strukturen und Perspektiven, kassel university press GmbH, Kassel, S. 57
[28] Niedersächsisches Ministerium für Ernährung, Landwirtschaft, Verbraucherschutz und Landesentwicklung/Niedersächsisches Ministerium für Umwelt und Klimaschutz (Hrsg.) (2010): Biogasnutzung in Niedersachsen: Stand und Perspektiven, S. 9
[29] Niedersächsisches Ministerium für Ernährung, Landwirtschaft, Verbraucherschutz und Landesentwicklung/Niedersächsisches Ministerium für Umwelt und Klimaschutz (Hrsg.) (2010): a.a.O., S. 13

4 Grassland's ecosystem services

The most important direct ecosystem service provided by grassland is the production of biomass for cattle feeding. Grassland also provides an essential anchor for maintaining biodiversity and accounts over-proportionally for protected or designated areas. For the regulation of the hydrological cycle, the high water absorption capacity of grassland is essential to reducing flooding. The cultural role of grassland linked to recreation and the provision of attractive habitats is often overlooked.

The outputs of grassland have been defined above as (I) provisioning, (II) regulating, and (III) cultural goods and services. There is an extensive national and international literature on this. This literature covers the general concept of ecosystem services as well as reports of detailed investigations of a variety of individual services and trade-offs between services. Here therefore the ecosystem services of grassland can be shown only in an overview or with reference to examples.

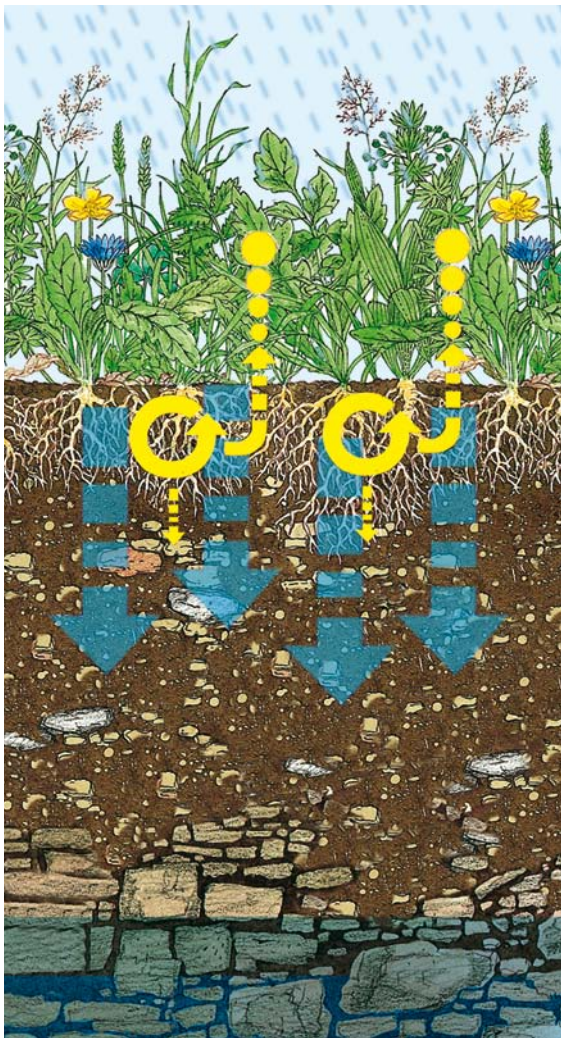
Provisioning goods and services

Production: food, feed, biomass

In the previous section, the production function of grassland has been presented in detail. There is a relationship between the quantity and especially the quality of biomass produced and the delivery of other ecosystem services. Site and management conditions affect outputs. The modification of these conditions, such as the regulation of hydrology in lowland areas is often an important prerequisite for the preservation and use of grassland areas.

Water

Grassland has a specific function in the regeneration of aquifers. Although groundwater recharge under grassland is lower than under arable land, grassland has clear advantages compared to forest, especially coniferous forest. The conversion of grassland into woodland or scrub is therefore usually associated with a reduction in groundwater recharge. For water resources, the quality as well as the quantity of recharge is important. Extensive investigations have shown that the nitrate content of leaching water is generally lower under grassland compared with arable land.[30] The pollution of the water with pesticide residues and their metabolites is also lower than on arable land because the frequency and scope of plant protection measures on grassland is generally low.



Extensively managed grassland with a low input of fertilizer has lower leaching losses of nitrate compared with arable land that is more heavily fertilised and on occasions free of vegetation.

[30] Cf. eg. Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU) sowie Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (BMELV) 2012: Nitratbericht 2012, S. 50 http://www.bmub.bund.de/fileadmin/bmu-import/files/pdfs/allgemein/application/pdf/nitratbericht_2012_bf.pdf#page=38&zoom=page-fit,-623,301
Im Gegensatz zur allgemeinen Situation besteht aber auch eine besondere Problematik in Nord-West-Deutschland entlang der Küste, einer Region mit besonders hohen Nitratwerten und gleichzeitig hohem Grünlandanteil.

Habitat for many insects: grassland supporting high levels of biodiversity.

Regulating goods and services

Biodiversity

More than a third of all plant species occurring in Germany and 55% of the endangered Red List species are potentially found in grassland areas. Many of our domesticated plants originated in grassland regions.[31] The genetic resources of grassland have an above-average importance because germplasm with valuable traits such as resistance to pathogens and further yet undiscovered or unused traits can be found on grassland for transfer to cultivated species. The species richness of grassland can directly support the productivity and stability of production.[32] Biodiversity also includes the diversity of animal genetic resources for food and agriculture.[33] Grassland is the production base for most indigenous and now endangered animal breeds.[34]

Pollination services and habitat provision

Species-rich permanent grassland is characterised by a high supply of flowers over a long period. Such grassland provides a habitat in the agricultural landscape that is attractive for a variety of flower-visiting insects.[35] Adjacent habitats also benefit from the pollination of flowering plants by insects. Insect pollination is important for the performance of several cross-pollinated crops. Species-rich grassland thus provides benefits for adjacent production areas, making it a natural resource (EU Biodiversity Strategy).

[31] McNeely J A, Gadgil M, Leveque C, Padoch C and Redford K 1995 Human influence on biodiversity. In Global Biodiversity Assessment. Ed. UNEPs. pp 715-821. Cambridge University Press, Cambridge.
Vavilov N I 1951 The Origin, Variation, Immunity and Breeding of Cultivated Plants. Soil Science 72, 482.
Bundesministerium für Ernährung und Landwirtschaft: Nationales Fachprogramm zur Erhaltung und nachhaltigen Nutzung pflanzengenetischer Ressourcen landwirtschaftlicher und gartenbaulicher Kulturpflanzen, 2012

[32] Tilman D, Reich P B and Isbell F 2012 Biodiversity impacts ecosystem productivity as much as resources, disturbance, or herbivory. Proceedings of the National Academy of Sciences 109, 10394-10397.

[33] Secretariat of the Conference of Parties: The Convention on Biological Diversity, 1992

[34] Bundesanstalt für Landwirtschaft und Ernährung: Rote Liste einheimischer Nutztierassen in Deutschland 2013, 2013, http://www.genres.de/haus-und-nutztiere/gefaehrdung/

[35] Kremen C, Williams N M, Bugg R L, Fay J P and Thorp R W 2004 The area requirements of an ecosystem service: crop pollination by native bee communities in California. Ecology Letters 7, 1109-1119.
Allan, E., Bossdorf, O., Dormann, C.F., Prati, D., Gossner, M.M., Tscharntke, T., Blüthgen, N., Barto, K., Bellach, M., Birkhofer, K., Boch, S., Böhm, S., Börschig, C., Chatzinotas, A., Christ, S., Daniel, R., Diekoetter, T., Fischer, C., Friedl, T., Glaser, K., Hallman, C., Hodaĉ, L., Hölzel, N., Jung, K., Klein, A.M., Klaus, V., Kleinebecker, T., Krauss, J., Lange, M., Müller, J., Nacke, H., Pašalić, E., Rillig, M., Rothenwöhrer, C., Schall, P., Scherber, C., Schulze, W., Socher, S., Steckel, J., Steffan-Dewenter, I., Türke, M., Weiner, C., Werner, M., Westphal, C., Wolters, V., Wubet, T., Gockel, S., Gorke, M., Hemp, A., Renner, S.C., Schöning, I., Pfeiffer, S., König-Ries, B., Buscot, F., Linsenmair, K.E., Schulze, E.D., Weisser, W.W. & Fischer, M. (2014): Interannual variation in land-use intensity enhances grassland multidiversity. Proceedings of the National Academy of Science, online first. doi: 10.1073/pnas.1312213111
Pufal, G. & Klein, A.M. (2013): Post-dispersal seed predation of three grassland species in a plant diversity experiment. Journal of Plant Ecology 6: 468-479

Calm after the storm on permanent grassland and arable land: effective protection against erosion through year-round vegetation cover contrasting with extensive deflation zones (light coloured areas) on crop land.

Grassland can temporarily absorb a lot of water and thereby provide effective protection against flooding.

Reducing soil degradation and erosion

Through year-round vegetation cover and the permanent, well-developed root system, the soil stability in permanent grassland is significantly increased compared to arable land.[36] This ensures that grassland generally has a higher infiltration capacity compared with arable land, with the result that a smaller proportion of water runs off. In addition, vegetation cover intercepts raindrops and this reduces the impact of rain on soil and aggregates. As a result, erosion is reduced on grassland sites.

Hydrological regulation

The soil protection effect of grassland vegetation is directly related to the high water retention capacity of grassland soils.[37] As the run-off of rainwater is small on grassland, less water enters drains and the risk of flooding on a landscape scale is reduced. Hydrological models show that the risk of flooding can be reduced by increasing the proportion of grassland in areas dominated by arable cropping.[38] Grassland is also an important land-use option for water retention areas along flood plains.

[36] Douglas J T and Goss M J 1982 Stability and organic matter content of surface soil aggregates under different methods of cultivation and in grassland. Soil and Tillage Research 2, 155-175.

[37] Thurow T L, Blackburn W H and Taylor Jr C A 1988 Infiltration and interrill erosion responses to selected livestock grazing strategies, Edwards Plateau, Texas. Journal of Range Management, 296-302.

[38] van der Ploeg, R.R., W. Ehlers und F. Sieker (1999): Floods and other possible adverse environmental effects of meadowland area decline in former West Germany., Naturwissenschaften 86, 313-319

Water quality

Natural and semi-natural grasslands are able to store significant amounts of nitrogen and thus to prevent nitrate leaching into surface water bodies or groundwater from soils that have low retention capacity or are prone to erosion.[39] The C-rich grassland soils have a considerable geochemical reduction potential that must be preserved even when intensively farmed. Grassland in principle increases the filtering and storage performance for mobile substances such as nitrate, potassium or phosphorus, if surface erosion is largely eliminated.

Reducing greenhouse gas emissions

Grassland can make a significant contribution to carbon dioxide, nitrous oxide and methane exchange between the atmosphere and biosphere. These fluxes are coupled to grassland management, soil type and climatic conditions.[40] Carbon sequestration and nitrous oxide emissions are influenced by these factors as well as by species composition.[41] Globally, grassland accounts for 34% of the total organic carbon stored in terrestrial systems.[42] For a given soil and climate, the quantity of soil organic matter in grassland is significantly higher than in arable land. The carbon balance of grassland use can vary with site and management and depends especially on the concentration of organic matter, soil water status, N fertilization (mineral and organic) and feeding practices. For a proper assessment, it is therefore necessary to generate an overall balance that includes the material flows of the production system and to evaluate the emissions per production output. Ultimately, ethical and social criteria also play a role. Thus, the methane emission of cattle production from grassland that cannot be used for arable cropping must be treated differently to production based on forage cropping as the former sites cannot be otherwise used for food production.

Cultural goods and services

Landscape aesthetics and recreation

Grassland provides further important cultural services. Large areas of grassland in Germany are man-made landscapes. Many of them are remnants of traditional agricultural land use practices and the product of thousands of years of interaction between humans and the environment. Without management, this grassland would largely transform by succession into forest. This cultural significance of grassland means that it plays an important role in maintaining tourism in the relevant regions.[43] Through this type of farming, the uniqueness of these landscapes is preserved.[44]

The openness of grassland is important to walkers, hikers and cyclists who appreciate the high aesthetic value as it is precisely the interplay between forests and open landscapes that is perceived as pleasant or is important for

[39] Phoenix G K, Johnson D, Grime J P and Booth R E 2008 Sustaining ecosystem services in ancient limestone grassland: importance of major component plants and community composition. Journal of Ecology 96, 894-902.

[40] Soussana J F, Pilegaard K, Ambus P, Berbigier P, Ceschia E, Cifton-Brown J, Czobel S, de Groot T, Fuhrer J, Horvath L, Hensen A, Jones M, Kasper G, Martin C, Milford C, Nagy Z, Neftel A, Raschi A, Rees R M, Skiba U, Stefani P, Saletes S, Sutton M, Tuba Z and Weidinger T 2004 Annual greenhouse gas balance of European grasslands – first results from the Green Grass project. In International Conference Greenhouse Gas Emissions From Agriculture – Mitigation Options and Strategies. pp 25-30, Leipzig, Germany.

[41] Conant R T, Paustian K and Elliott E T 2001 Grassland management and conversion into grassland: Effects on soil carbon. Ecological Applications 11, 343-355.
Follett R F, Kimble J M and Lal R 2001 The potential of US grazing lands to sequester soil carbon. In The Potential of US Grazing Lands to Sequester Soil Carbon. Eds. R F Follett, J M Kimble and R Lal. pp 401-430. CRC Press, Chelsea, MI.
Chapuis-Lardy, L., Wrage, N., Metay, A., Chotte, J.-L., Bernoux, M. (2007). Soils, a sink for N2O? A review. Global Change Biology 13, 1-17

[42] White, R.P., Murray, S., Rohweder, M., (2000): Pilot analysis of global ecosystems - Grassland ecosystems. World Resources Institute, Washington D.C

Grassland is an important characteristic of cultural landscape used for recreation.

hunting. The aesthetic value is increased by the presence of grazing animals. Local breeds contribute to the value of landscape and enhance the identification of people with the region and with the grassland. Meadows and pastures near settlements support leisure activities, such as football matches or horse riding in the summer or skiing in winter. This underlines the recreational value of grassland areas, which is used for regional marketing and is also measurably reflected in the regional value added in many places (rural tourism, cycling, rural gastronomy, etc.).

Trade-offs between provisioning and other ecosystem services

There is often the expectation in society that grassland should deliver a wide range of ecosystems services simultaneously and to a high degree. Generally, this expectation cannot be met. There are clearly pronounced trade-offs between the various services. Figure 3 uses spider web diagrams to show two examples of the delivery of various ecosystem services from grassland.

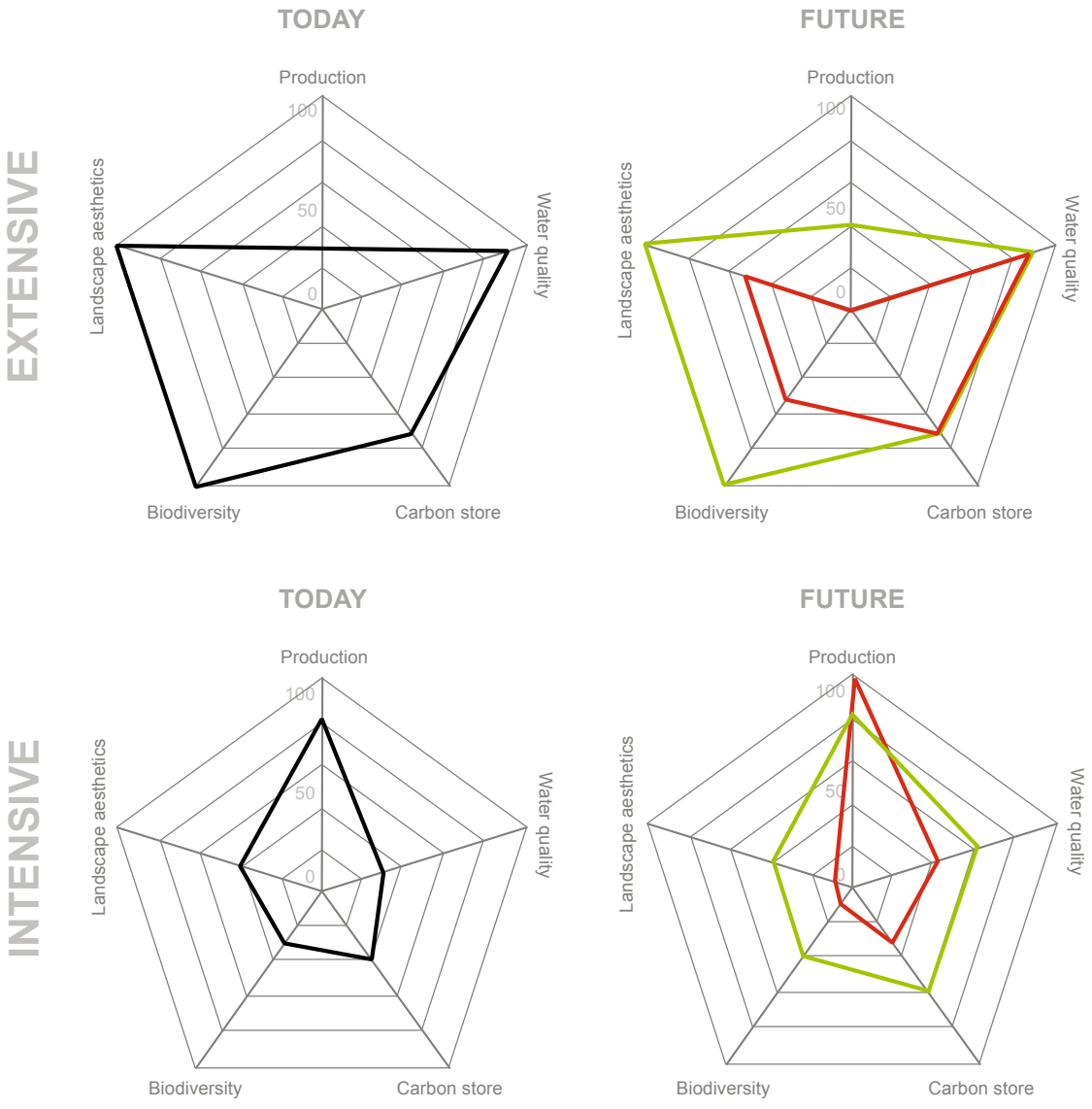
Extensive grassland is characterised by low agricultural output, but with high production of other ecosystem services. The abandonment of extensive grassland for agricultural purposes means that the output falls back to zero. Other ecosystem services initially remain unaffected. With time and proceeding succession, the delivery of non-provisioning ecosystem services such as biodiversity or of cultural value declines. In these circumstances, it would be beneficial to conserve production or to even promote a moderate increase in production to provide and develop other ecosystem services.

On the basis of currently intensively managed grassland (Figure 3, lower part), the development goal would be the maintenance or increase in productivity while increasing or maintaining other services.

[43] Parente G and Bovolenta S (2012): The role of grassland in rural tourism and recreation in Europe. In Grassland Science in Europe, Volume 17. pp 733-743. Polskie Towarzystwo Łąkarskie (Polish Grassland Society), Poznań.

[44] Plieninger, T. and Reinholz, A. (2004): Landscape-Level Conservation. Modern management of traditional lands: A case study of common rangelands in Germany's Southern Black Forest. Rangelands 26 (6), 16-23.

Figure 3: Examples of patterns of ecosystem service provision across different grassland types (extensively or intensively managed grassland) and development scenarios



red: undesirable; green: wanted
The ecosystem service delivery varies between 0 (no or even negative performance) and 100 (maximum possible performance under the prevailing conditions). Research efforts should be planned to achieve the scenarios marked green.

- *Extensive/red: Abandonment of agricultural production, loss of ecosystem services.*
- *Extensive/green: Agricultural use continued, moderate increase in production, no change in other ecosystem services.*
- *Intensive/red: Further intensification, change to temporary grassland, increased productivity, loss of diversity and cultural services.*
- *Intensive/green: No further increases in production, increases in other ecosystem services.*

These are illustrations of trade-offs, but this insight tells us little about the causes of trade-offs. However, knowledge of these functional relations is needed when it comes to manipulating or reducing trade-offs through adaptive management. The relationship between various ecosystem services from grassland is characterised by a variety of interacting factors. Gaining a better scientific understanding of such complex systems and deriving optimal management strategies requires sophisticated models.

Managing trade-offs is a key challenge of the development of grassland-based farming systems. Farmers play a central role as the key decision-makers in grassland management. In managing trade-offs, priority should be given to optimising the provision of ecosystem services that characterise grassland and are expected specifically from grassland.

Prioritization should be carried out in a holistic societal context. With an appropriate policy framework, the economically-based decisions made by farmers can be aligned with the expectations of society.

5 Goals – what is to be done?

The Research Strategy supports research for the development of innovative value chains based on grassland farming with site-specific and practice-relevant approaches. There must be a special focus on new income opportunities based on biomass production combined with rewards for socially relevant ecosystem services. Research should support innovation and related assessment models.

In the previous sections, the special value of grassland, much of which is under-appreciated so far, has been outlined. Compared to other ecosystems (e.g. forest, arable land), grassland is unique. From a societal perspective, it is therefore desirable to couple provisioning services based on biomass production and use (for milk, meat, energetic or material use), with other ecosystem services so that an optimal societal outcome arises. Since grassland in temperate zones depends on agricultural use for its existence, the preservation and increase in its value has to be seen in the context of its future use. This is true for both intensive and extensive production systems. Taking dairy farmers as representatives of major grassland users, the development of completely new approaches may be required. The profitability of grassland can be secured or increased if a) milk production per unit area rather than per lactating cow is in focus, b) in calculating pasture performance, the maintenance requirements of the animal are proportionately attributed to the different fodder types ingested[45] and c) the requirements and impact of producing replacement heifers is included in assessments. This requires production-related technical, organisational and socio-cultural innovations in grassland management that must be accompanied by a series of changes throughout the production system. This includes for example breeding dairy cows for high utilisation of forage and adaptation to grazing, innovative management concepts, or novel collaborations along the value chain from producer to consumer.

Site-specific characterisation of grassland – precondition for an efficient use.

The development of new production and management systems has in the last two decades occurred mainly on other types of land use than grassland. The aim of the DAFA Grassland Export Forum was therefore to develop a research strategy to support innovative exploitation of the value-added potential of grassland with regard to both the site and agricultural practice. From the perspective of agricultural practice, the value creation potential includes both income opportunities from production as well as the remuneration of certain ecosystem services that are of particular benefit to society, for example, through agri-environment and climate protection measures. Therefore, the evaluation systems must place equal emphasis on production systems throughout the value chain and on other ecosystem services and causal relationships up to civil society participation in order to holistically determine the value of

[44] Leisen, E., Spiekers, H., Diepolder, M. (2013): Notwendige Änderungen der Methode zur Berechnung der Flächenleistung von Grünland- und Ackerfutterflächen mit Schnitt oder Weidenutzung. In: Bayerische Landesanstalt für Landwirtschaft, 57 Jahrestagung der Arbeitsgemeinschaft für Grünland und Futterbau der Gesellschaft für Pflanzenbauwissenschaften e.V., Schriftenreihe, S. 181-184. Cleven M., Verhoeven A., Pries M., Berendonk C. and Wrage-Mönnig N. (2015): How much milk is produced from pasture? Comparison of two calculation methods. In: Grassland Science in Europe, Vol. 20 – Grassland and forages in high output dairy farming systems

[45] Geneletti, D. (2013):. Multi-criteria analysis. LIAISE Toolbox. Retrieved 2015-03-12 from http://beta.liaise-toolbox.eu/ia-methods/multi-criteria-analysis

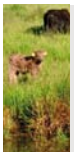
A grassland field trial.

grassland. Multi-criteria analysis[46], which is already used in ecosystem management, should be used for holistic assessment.[47] The achievement of the objectives requires significant research and development efforts, as well as an adaptation of the research infrastructures. The research activities should aim to produce changes or adjustments in grassland management practices in the medium term. Therefore, the development of operational concepts for extension services and the inclusion of social aspects play a special role.

The DAFA Grassland Expert Forum sees the following needs: By means of system-oriented research, the innovation potential needs to be identified, developed and realised into practice-ready research outputs. Because innovations to develop the future production systems must support a wide range of other ecosystem services, this requires new, interdisciplinary and transdisciplinary research approaches and concepts for knowledge generation and transfer into practice. As the grassland types and their potential are highly variable for provision of ecosystem services, the priorities concerning expected services differ greatly accordingly. In intensively used grassland, the priority is on increasing the effective production output and resource-efficiency while fostering and assuring the co-production of regulating services. In extensively managed species-rich grassland, further development of site-specific management methods for providing and marketing regulating and cultural services are in the foreground. Particular attention should be paid to the development of adequate valuation methods, as with the above-indicated approach solutions for managing trade-offs need to be found. These valuation methods need to include not only technical and economic parameters but also the perspectives relating to the societal appreciation of grassland and grassland protection.

The Expert Forum recommends on the basis of the analysis above that research activities be undertaken for the following product lines that are very relevant in practice.

Protein from grassland
Innovation in milk production



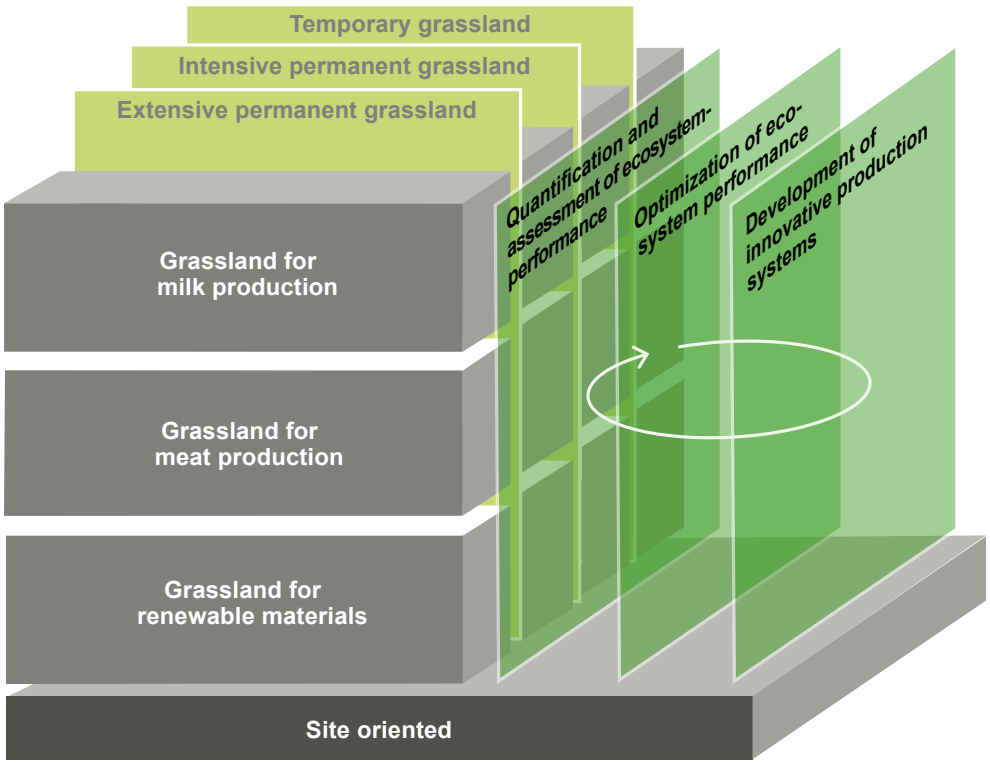
Meat better from grassland
Innovation in meat production

Grassland: a new source of raw materials
Innovation for use as a renewable resource

[47] E.g.: Kennedy, Maureen C., Ford, E. David, Singleton, Peter, Finney, Mark and Agee, James K. (2008): Informed multi-objective decision-making in environmental management using Pareto optimality. In: Journal of Applied Ecology, Volume 45, Issue 1, pages 181–192, February 2008
http://dx.doi.org/10.1111/j.1365-2664.2007.01367.x
Cinelli, Marco, Coles, Stuart R. and Kirwan, Kerry. (2014): Analysis of the potentials of multi criteria decision analysis methods to conduct sustainability assessment. In: Ecological Indicators, Volume 46 . pp. 138-148. http://dx.doi.org/10.1016/j.ecolind.2014.06.011

These production lines are then related to the location and the different types of grassland. In the intersections between research fields and grassland types, site-adapted innovative production systems should be sought and developed with corresponding definition, quantification and evaluation of ecosystem services. Figure 4 illustrates the systematisation of research challenges as described in this Grassland Strategy.

Figure 4: Conceptual framework of the DAFA Grassland Research Strategy



6 Innovation/research needs

Applied research must be site-specific and organised to serve the important value-chains such as milk production, meat production and renewable materials. Ecosystem services and economic performance must always be jointly considered. From a research structure perspective, collaborative projects should examine several types of ecosystem services such as biomass production, biodiversity, carbon sequestration, water regulation and landscape aesthetics holistically together with their interactions. Various research disciplines and representatives from agriculture, public policy, environmental and nature conservation must be involved in research partnerships.

Cornerstones for a Grassland Research Strategy

The development of innovative, grassland-based production systems represents a particular challenge for research. Meeting this challenge requires an increase in collaborative, systems oriented research that investigates value-chain oriented networks comprehensively and that combines disciplines in a joint research effort taking into account the working environment of the different actors and institutions in a transdisciplinary way. Research funding organisations should support these challenges with appropriately designed new lines of funding.

Organisation of research and research content

Grassland systems are complex. Relevant, effective research must take this complexity into account. This can only be achieved through interdisciplinary and transdisciplinary approaches pursued within collaborative research partnerships and characterised as follows:

Focus on the introduction and testing of innovations within defined production systems.

Innovation in production and utilisation systems conducted in a site or landscape context.

System-oriented research, interdisciplinarily, with innovations analysed from different perspectives, e.g. production-related, ecologically, or socio-economically; value-chains play an important role. The relevant scientific disciplines must be combined with expertise specific to grassland.

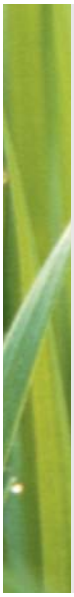
The aim of scientific investigations is the development or adaptation of innovative production systems, the quantification of ecosystem service provision from these as well as the assessment of services and trade-offs. In each research partnership, regulating and cultural ecosystem service provision (e.g. biodiversity, carbon sequestration or hydrological regulation) must be investigated in addition to production performance to verify synergy effects.

The research consortia must work in a transdisciplinary way. There should be representation of agriculture, environment and nature protection, pre-farm and post-farm actors, social sciences, administration and public policy.

The research content can be classified in terms of the products of grassland management, of grassland type and the nature of public services. The grassland types include regularly regenerated or seeded, intensively farmed temporary grassland, intensively managed permanent grassland and extensively managed permanent grassland. This differentiation by grassland type is needed because it influences production and the output of regulating and cultural services and the trade-offs among them. In addition to these main classification factors, the site of production needs to be considered. Permanent grassland can be found in Germany on very different locations and under different climatic conditions and clearly all production systems for all conditions are not alike. As described in section 5, research should be aligned to milk production, meat production, and grassland as a source of renewable industrial materials.

In the following, the areas for which the DAFA Grassland Expert Forum has identified a particular need for research will be described in more detail. These Research Fields describe research activities within product lines that lead to the development of innovative production systems. These systems are intended to support multiple ecosystem services through optimised use of grassland, be economically and fulfil societal expectations of the grassland. Research of production lines should relate to the following activities:

The objective description, quantification, possibly optimisation and evaluation of ecosystem services are of fundamental importance, e.g. biodiversity; attractiveness of grazing systems in the cultural landscape and their contribution to landscape cultural identity; water regulation and water quality, carbon sequestration, reducing emissions of climate-relevant gases (nitrous oxide, methane, CO_2) in milk, meat or biomass production as a function of the production systems, grassland types and site conditions (permanent grassland in lowland and mountain areas, grassland in protected areas; site-specific process design) and the provision of a diverse or typical regional landscape (recreational, cultural landscape, tourism etc.).



Economic effects of grassland utilisation improved by economic assessment and modelling of all services, through marketing, by design of agricultural policies and conditions (e.g. the EU's CAP), through development and implementation of management approaches for a high proportion of grassland in feeding, through cascading uses and by site-specific approaches to coordinating the different user interests in the various permanent grassland sites.

A higher proportion of grass silage in the dairy cow ration – more protein from grassland.

6.1 Protein from grassland – Innovation for milk production

For the widespread maintenance of grassland, intensive dairy farming is clearly the most important activity in terms of both land occupied and the value of output. This includes the rearing of young cattle to provide replacement heifers for the dairy herd. Through different fodder requirements, limited use of 'extensively' farmed grasslands can also be worthwhile. There is innovation potential throughout the value chain from forage production, preservation and feeding, to the resulting products and process quality. Promising innovations should be integrated into knowledge exchange concepts to ensure rapid implementation on the farms. The acceptability of these innovations to consumers and society in general should be considered.

Improved resource efficiency and value creation can be achieved with different production intensities depending on location. The aim is in each case to realise the highest eco-efficiency of production, i.e. to identify the production intensity and technology that results in the least negative trade-offs (e.g. emissions per unit of produced food).[48]

Regardless of the intensity of milk production, increasing the protein supply to animals from grassland is a central objective.[49] This not only improves the resource utilisation efficiency and reduces import demand for protein feed, but has also enormous potential for improving the quantitative protein supply of dairy cows from domestic protein sources. Starting points can be found along the whole process chain from plant breeding (influencing the protein quality of grasses, legumes and herbs), fertilisation, timing of grazing or cutting, forage feed conversion, rationing, to the modelling of this entire process chain. The following research needs for using grassland for dairy production need to be addressed primarily through interdisciplinary activity:

Research fields

- **Increasing the supply of protein from grass to the dairy cow:** increase the nitrogen utilisation and nitrogen uptake efficiency of forage grasses with simultaneous heat and drought tolerance; alteration of protein metabolism of grasses through breeding (e.g. increasing the proportion of cell wall bound protein); quantifying the transformation processes of crude protein during ensiling; development of innovative hay and haylage technologies for protein-rich substrates (e.g. alfalfa); modelling of yield determining processes,

[48] Taube, F. (2013): Der zukünftige europäische Weg - Ist nachhaltige Intensivierung möglich? - Europas Beitrag zur zukünftigen globalen Agrarproduktion. Landwirtschaft im Konflikt mit der Gesellschaft, Archiv der DLG, 107, 17 -42. Hrsg.: DLG e.V., Frankfurt am Main; DLG Verlag GmbH, S. 30

[49] Cf. zur Erhöhung des Proteingehalts in Feldfutterbau und Dauergrünland auch die Ziele der Eiweißpflanzenstrategie des BMELV, 27.11.2012, Kapitel 3.2.2, S. 4, www.bmel.de/SharedDocs/Downloads/Broschueren/EiweisspflanzenstrategieBMELV.pdf?__blob=publicationFile

Grassland for rearing young cattle – use also of dispersed permanent grassland.

N uptake and protein quality of intensive grassland and extensive permanent grassland for optimised protein use and preservation of natural diversity in permanent grassland; genetic improvement of the quality and characteristics of secondary compounds (PPO; tannins) to increase the usable protein from grass products; further development of in-vitro methods to simulate the kinetics of protein degradation in the rumen; synchronisation of protein and energy degradation in the rumen of different breeds; increasing the botanical diversity of intensive grassland using protein-rich forage plants (herbs, legumes). Investigation of the influence of plant ingredients on microbial protein synthesis in the rumen. Development of extension tools to optimize the protein utilisation efficiency of grassland; use of ingredients from herbs for N utilisation and absorption in the rumen;

- **System innovations for protein:** An essential prerequisite for innovation is the combination of the aforementioned disciplinary activities applied at an interdisciplinary level by the development, use and linking of models that promote the understanding of processes and allow aggregated assessments of innovations. Description, quantification, possibly optimisation and evaluation of the trade-offs of the protein strategy (e.g. biodiversity, hydrological regulation and water quality, carbon sequestration, reduced emissions of climate-relevant gases (nitrous oxide, methane, CO_2)), assessment of domestic protein provision in terms of international effects on (indirect) land-use changes.

- **System research for milk from pasture:** Grazing management has great potential for innovation. It is subject to no preservation losses, has relatively high feed intake of the highest quality forage without supplementary feed and offers clear advantages in terms of animal nutrition and animal welfare. In addition, production based on grazing enjoys high consumer acceptance. Innovative grazing systems need to be developed in the context of different production intensities, farm types, and for different site conditions (consolidation of land, soil quality, precipitation, etc.): evaluation criteria, grazing systems, young cattle rearing; full grazing for milk production; limited grazing periods; farm performance assessment and modelling; marketing of pasture milk. Development of added value concepts for ‘pasture milk’ taking into account animal breeding and selection, engineering (automated milking in grazing systems), pasture management (modelling growth and forage quality), herd management (e.g. seasonal calving,

full grazing / partial grazing), animal nutrition (rationing) and farm economics and ecology (reorientation of the economic evaluation of environmental effects such as biodiversity, GHG emissions 'carbon footprints'; nutrient efficiency), marketing approaches, design of agricultural policies (pasture premia). Development and implementation of appropriate management approaches in grassland regions (pilot, model farms).

6.2 Meat better from grassland – Innovations in meat production

The requirements for feeding and husbandry of animals, mostly cattle and sheep, for meat production on grassland, their breeds, and their groups or stages of production vary enormously. The resulting range of feed requirements can be met by various grassland regrowths and locations, including especially environmentally valuable sites and nature conservation areas that are e.g. managed for the protection of grassland birds and grazed only at certain times or for landscape maintenance and continuation of grassland use itself. Increased use of grasslands for meat production would also help to reduce the demand for feed from arable crops. Consistent use of pasture for grazing contributes to meeting expectations for improved animal welfare in society.

The above-mentioned and other ecosystem services are rewarded through extensification and conservation programs financed by EU funds, the Federal and State governments since the 90s. Without these payments, which are continuously scrutinised from a fiscal perspective, economic meat production on grassland is not possible. This is especially true for

Meat production through keeping suckler cows and calves on species-rich grassland: new, economic and environmentally beneficial approaches need to be developed.

sheep production. Therefore, long-term support for such payments depends on the range of ecosystem services that are co-produced with meat, their definition, quantification and monetary valuation. At the same time, the study of production and marketing strategies is required to increase economic competitiveness because the duration and the level of public funding are uncertain. Priority thematic areas are as follows:

Research Fields

- **System Innovations:** Development of innovative marketing systems for products of grazing with beef cattle and mutton sheep, taking into account regional differences, product qualities and breeds.

- **Developing innovative grassland production systems with beef cattle and mutton sheep:** low cost options of meat

The use of grassland biomass for energy – large potential in many regions.

Research on processing grassland biomass for energy use has started – more research for material uses is required.

production based on grazing; protein supply from grassland as an alternative to feeding based on maize/soy/concentrates, considering site and socio-political expectations, farm and herd size, animal welfare, timing of calving, weaning, sale, over-wintering of animals, cost-effective winter feeding, use of dispersed extensive grasslands, combination of milk and meat production from pastures e.g. using dual-purpose breeds. Adaptation of assessment procedures (multi-criteria analyses).

- **Production systems in the context of agri-environment schemes:** Development of agri-environmental schemes for the promotion of non-marketable ecosystem services from grassland such as biodiversity, carbon sequestration, improving the integration of temporal and spatial scales (effects of grassland-related agri-environmental schemes at farm and landscape scale as well as in protected areas), effect of specific features of livestock species / breeds and production systems on ecosystem services, including cultural services. The advancement of appropriate assessment approaches also plays an important role in this context, also concerning the “appreciation” of the often considerable commitment of the participating farmers.

6.3 Grassland: the new source of raw materials – Innovation for use as a renewable resource

Grassland biomass so far plays a minor role for energetic and material uses. In particular, in grassland-rich regions of Germany (e.g. mountain regions, riparian areas) animal-

based exploitation of grassland dominates. On low-yielding sites, management is increasingly characterised by a minimum level of care using mowing without use of the mown grass. The energetic and material non-food use should serve as an alternative or additional use of underexploited grassland so as not to increase the pressure on land for food and feed production. Non-food production systems should be developed that can be integrated into the rural areas and within farms and existing animal-based grassland systems. Flexibility regarding the quality of the biomass used is conducive to innovation. Priority thematic areas are as follows:

Research Fields

- **Systems for biomass use without animals:** Innovative, optimised processes for the flexible and efficient use of biomass unused in livestock production (e.g. regrowths of meadows and pastures, meadows far from the farmstead, and mown high nature value grasslands). Improved methods for undisturbed sensor-based recording of quantity and quality of grassland biomass for more efficient harvesting operations as well as for large-scale survey of the biomass potential and the site-specific / field-specific prediction of biomass yield. Adaptation of assessment procedures (multi-criteria analyses).

- **Combined production systems:** Development and analysis of the productivity and environmental performance of systems that combine animal-based, energy and material use of grassland based on long-term experimental data and using adequate modelling approaches.

7 Conclusion and perspective

The utility of grassland must be improved to increase the value of its management. Strong transdisciplinary research consortia should provide an impulse to economically viable innovations that can be implemented in practice to support the joint delivery of different types of ecosystem services from the same site.

The DAFA Grassland Expert Forum concludes that priority in research must be given to better tapping the potential of grassland and thus increasing the value of grassland management. This goal is not only important from an agronomic perspective. It is necessary in the interest of society as a whole to make biomass production on grassland and its exploitation (milk, meat, industrial raw materials) attractive because important ecosystem services delivered by grassland are linked to its management and use. Since provisioning services and other ecosystem services from grassland can vary greatly depending on management intensity and location, economically viable production systems for different grassland types (extensive permanent grassland, intensive permanent grassland and temporary grassland) need to be designed to systematically increase multiple services of grassland.

Grassland accounts for just about one third of the agricultural area – a common research approach to better use all ecosystem services it provides and a suitable policy framework is the foundation of optimism for the future.

The Research Fields define a wide target area. The DAFA Grassland Expert Forum expects that based on the identified research and development needs, effective inter- and transdisciplinary alliances that creatively meet these challenges will emerge.

This expectation can only be fulfilled if research funding organisations develop research programs or calls implementing the outlined emphasis as regards content as well as addressing the diversity of grassland sites in Germany. The DAFA Grassland Expert Forum regards the research initiative outlined only as a first step to improve the performance of grassland. In a second step, innovative knowledge transfer projects need to follow to ensure that the innovations arising from research are quickly and efficiently transferred into agricultural practice.

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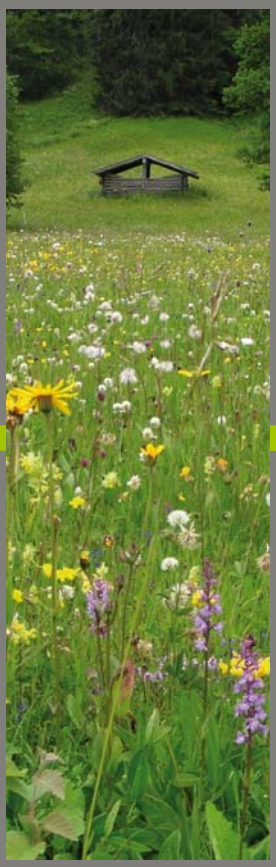

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