EIP-AGRI Focus Group
Permanent Grassland

Sustainable grassland production by increased functional group diversification

AUTHORS: Piotr Goliński, John Bailey, David Gomes Crespo, Agnes van den Pol-van Dasselaar, Vibeke Lind, María Rosa Mosquera-Losada, Michael O'Donovan, Alain Peeters, Claudio Porqueddu & Dirk Reheul

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Introduction

An important factor governing the sustainability of grassland-based production systems is sward composition. Depending on climate and soil conditions, the make-up or functional diversity of grassland communities can significantly influence a number of ecosystem services, including air and soil quality regulation, crop pollination and pest control, bio-energy and fibre production, and human recreation and aesthetics. A first challenge is to identify the optimal mixture in different climate and soil conditions to simultaneously contribute to multiple ecosystem functions. Furthermore, developing management practices to establish and maintain permanent grassland which optimises productivity and climate change adaptation through functional group diversity presents a major challenge to agronomists and land managers. Difficulty in maintaining well-balanced mixtures in swards is one of the main reasons why highly productive grasslands generally consist of pure grass swards associated with 'high' inputs of synthetic fertilisers that are usually spread under no restricted environment conditions. The true functional benefits from increasing sward diversity can only be appreciated when multiple ecosystem processes are considered simultaneously (Hector and Bagchi, 2007).

In productive grassland systems it would clearly be useful in practical terms if a positive diversity effect could be obtained from a mixture of just a few species, well adapted to the prevailing environmental conditions, than having to rely on highly diverse communities of species (Lüscher *et al*., 2007). Under sub-optimal and variable environmental conditions, as in many pastoral farming systems of the Mediterranean basin and transitional areas, the maintenance of a high level of inter and intra-specific diversity is essential to achieve satisfactory and persistent pastures. When the improvement of the native sward is needed, the choice to use pasture mixtures instead of single species seems more appropriate in low input grasslands (Dear and Roggero, 2003). Long lasting "Biodiverse Legume-Rich Sown Permanent Pastures (BLRSPP)" formulated according to the local soil and climate conditions may yield, without the application of synthetic nitrogen fertilizer, considerable amounts of dry matter of high quality, at least able of doubling the carrying capacity when compared with natural permanent grasslands with low participation of legumes. In the Atlantic area, the presence of mixed pasture with legumes instead of monoculture of ryegrass increases both productivity per unit of hectare and extend the grazing season. Legumes are not enough utilized for increasing quantity and feed quality of permanent grassland production in the different biogeographic regions of Europe. The potential for legumes to contribute to sustainable grassland management more resilient to climate change relates also to their ability to: 1/ reduce or even eliminate the requirements for inorganic N fertilisers derived from non-renewable sources of energy; 2/ reduce losses of nitrogen to the environment, 3/ reduce the need for high cost imported concentrates and 4/ maintain and improve soil structure and fertility. Benefits can also be obtained by some grassland herbs. The presence of functional traits associated to woody vegetation is advantageous in permanent grasslands because of its increasing biomass production through the better use of the resources at both soil (soil volume explored for uptaking nutrients is higher) and aerial (radiation) part of the permanent grassland. The Land equivalent ratio (LER) is higher under agroforestry conditions. Woody vegetation is able to provide a better productivity and ecosystem services helping to herbaceous grassland species to be more resilient under changing conditions, recently caused by climate change. Agroforestry has been identified as an adequate practice related with climate change by the IPCC (2014) and the CAP (Regulation 1307, 2014). Therefore, the promotion of multispecies sward and diversifying functional groups in the sward composition are crucial for sustainable grassland-based production systems.

A primary objective of the EIP Agri Focus Group on Permanent Grassland is to improve the efficiency and productivity of grassland-based agriculture whilst simultaneously reducing its carbon footprint and enhancing associated biodiversity. The aim of this paper is to contribute to this objective by: (1) identifying available practices and techniques which can improve the feed quality and quantity of sward biomass production; (2) identifying existing research of relevance; (3) showing where further research is required; and (4) outlining the innovative actions needed to translate scientific knowledge of increasing feed quality and quantity of grassland by diversifying functional groups into practice.

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Practices and techniques

There are many practices and techniques with high impact on vegetation composition and farming type of grasslands in different regions:

Practices and techniques affecting grassland productivity

- Breeding/selection of new grass and legume species and varieties better adapted to climate change (e.g. more winter hardiness or drought tolerance) like *Lolium-Festuca* genotypes (Ghesquière *et al.*, 2010)
- Improved techniques of grassland establishment: i.e. appropriate sowing date, sowing depth, seed inoculation, composition of mixtures considering proportions of functional groups of species
- Use of multi-species mixtures for grassland establishment and renovation to increase sward stability and productivity in comparison to monoculture swards
- Use of mixtures of phenologically different cultivars within species to improve the supply of forage during different growth periods
- Introduction of legumes and herbs into pasture to enhance productivity, sward palatability, quality (digestibility) and herbage intake by grazing animals
- Use of lime fertilizers/amendments (i.e. granular oxide/Ca+Mg carbonate) on specific acidic sites considering Al saturation rate to improve legume establishment and persistence in multi-species swards
- Optimum use of organic fertilizers (i.e. manures) to maximise nutrient-use efficiency, reduce nutrient losses to water and air and improve grass production, through manipulating timings, dose and methods of application
- Applying fertilizers in accordance with plant requirements and soil nutrient levels to increase productivity, profitability and sward stability
- Use of effective and ecologically friendly methods of sward renovation (e.g. over-drilling on organic soils) to improve fodder yield and quality without negatively affecting the environment
- Optimising grazing technique (stocking density and grazing pressure applied in the adequate period) to improve pasture production and quality, sward intake and animal production and reduce nutrient emissions/losses from faeces
- Optimum combination of grazing and mowing
- Zero-grazing (mowing only) will lead to a higher grassland production per year in highly fertilized swards, but the cost per feed unit suffers a considerable increase when moving from grazing to cutting
- Extending the grazing season to increase productivity and maximise resource use efficiency (winter grazing in Atlantic climate, grazing during all the year in Mediterranean zones)
- Prevention of weed species occurrence in swards, which negatively impact on forage yield and quality (e.g. *Poa trivialis*, *Rumex obtusifolius, Cirsium sp., Senecio jacobaea, Deschampsia cespitosa, Anthriscus sylvestris, Filipendula ulmaria*), by using well composed seed mixtures at establishment, and adopting sustainable management practices thereafter, using machinery alone or combined with grazing, etc.
- In silvopasture practices, select appropriate livestock to be feed in silvopastures which depends on type, density of trees and adequate management protocols to optimise grassland productivity
- Use of agroforestry practices to promote biodiversity and increase pasture production, in-farm feed resources, quality and ecosystem services per unit of land; in those permanent grasslands based on shrubs maintain an adequate proportion of woody vegetation to fulfil the shortage periods as much as possible and reduce fire risk avoiding GHG emissions

Practices and techniques affecting the feed quality of grassland swards

- Maximum use of legumes (optimum proportion legumes-herbs to grasses depending on site characteristics) in permanent grasslands to improve protein self-sufficiency, reduce mineral fertilization and minimize the amounts of supplementary feed required and nutrient environment losses with an improvement of carbon footprint
- Promotion of legumes by inoculation of seeds of different species with specific effective *Rhizobium* strains to assure an efficient symbiotic N fixation

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- Use of high quality grass cultivars in seeds mixtures (e.g. high-sugar ryegrasses, low lignin content) to improve production efficiency of ruminant livestock and reduce environmental N-pollution (better carbohydrates to protein ratio, better digestibility)
- Optimising sowing dates and rates, timely reseeding
- Avoidance of excessive fertilizer rates, particularly N and K fertilizers, to reduce the risk of high nitrate concentrations and high (Ca+Mg)/K ratios in herbage
- Use adequate proportion of legumes and forbs rich in tannins to maximise protein utilisation, prevent bloat in grazing ruminants and suppress internal parasites as well as produce healthier food
- Optimising time of cutting, particularly before and after first regrowth, to increase pasture density, reduce flowering and maximise the nutritive value and digestibility of herbage later in the season; harvesting at an early stage of growth (either via grazing or via mowing) will increase feed quality of the harvested material but decrease annual production
- Removing toxic plants from extensively used flower-rich meadows, e.g. *Colchicum autumnale, Ranunculus sp., Pteridium sp.*, *Oenanthe crocata* which can affect animal health or even cause mortality
- Optimise forage conservation techniques to avoid nutrient losses, mitigate the risk of forage contamination (e.g. mycotoxins accumulation in silage or hay) and minimize the use of maize and concentrates
- Optimising grazing management to avoid faeces effects, which lead to grazing losses and thus reduced yield; the negative impact of faeces can be minimized through an abundant presence of dung beetles, which can be enhanced through good practices of pasture establishment and management leading to an increase of soil organic matter and improved soil structure
- Use of appropriate methods and machinery for conservation procedure in dependency on sward botanical composition and vegetation season to avoid losses of herbage yield and quality
- Increasing pasture quality and resilience by using in agroforestry systems by woody vegetation shade and barriers (windbreaks, hedges) which usually reduces the flowering capacity, drought effect, nutrient leaching

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Research projects

COST Action 852

The collaborative project entitled "Quality Legume-Based Forage Systems for Contrasting Environments" (http://www.cost.eu/domains_actions/fa/Actions/852) focused on increasing the quantity and quality of home grown proteins from regionally adapted legume-based forage systems. Results have been obtained in the area such as the effects of grass-legume mixtures on plant yield, weed invasion, arthropod communities, soil microorganisms, gaseous N-losses, nitrate leaching and forage quality (Finn *et al*., 2013).

LINK Project LK0638

LINK Project LK0638 "High-sugar ryegrasses for improved production efficiency of ruminant livestock and reduced environmental N-pollution" was realised by IGER. The aim of this project was to provide sound scientific evidence for the advantages (production and environment) of using novel ryegrasses bred for their high sugar (water soluble carbohydrate) content in conventional plant breeding programmes, in grassland-based, low-cost dairy, beef and sheep production systems (Miller *et al*., 2001).

Forbioben

The FORBIOBEN "Integrating foraging attributes of domestic livestock breeds into sustainable systems for grassland biodiversity and wider countryside benefits" (http://cordis.europa.eu/project/rcn/58812_en.html) project within FP5 aimed at investigating the potential effects of managing semi-natural grazed grasslands mainly for enhancing their biodiversity compared to managing for efficient livestock production. As part of the project, researchers focused on the foraging behaviour of grazing animals and how this is influenced by the management intensity and selection of breed types (Rook *et al.*, 2004).

Multisward

The MULTISWARD project "Multi-species swards and multi scale strategies for multifunctional grassland-base ruminant production systems" (www.multisward.eu) was a joint research project within FP7. The aim of the research workpackage concerning the topic of this paper was to investigate the feed provisioning aspects of multispecies sown swards and permanent grassland in comparison with monocultures in terms of the relationships between sward diversity, sward dynamics, agronomic performances and nutritional value.

Permed

By adopting a multi-national approach and targeting the key breeding objectives of superior drought tolerance and water use efficiency, the project PERMED "Native perennial forage plants for sustainability of farming systems in the Western Mediterranean" (http://cordis.europa.eu/project/rcn/75644_en.html) within FP6-INCO aimed to evaluate elite lines of a select number of species of broad regional interest and adaptation. The project contributed to the development of technical packages for easy on-farm adoption of legume-based mixtures across the western Mediterranean (Franca *et al*., 2007).

Agforward

The overall goal of the project AGFORWARD "AGroFORestry that Will Advance Rural Development" (www.agforward.eu) within FP7 is to promote agroforestry practices in Europe that will advance sustainable rural development, i.e. improved competitiveness, and social and environmental enhancement. To achieve this, the project has four main aims: 1/to improve our understanding of the technical, environmental and socio-economic functioning of existing, and new extensive and intensive agroforestry systems, 2/to identify, develop and field-test innovations related to provisioning and other ecosystem services (biodiversity, carbon storage, nutrient cycling, resilience, stress toleration) to improve the benefits and viability of agroforestry systems in Europe, 3/ to develop and update designs and practices adapted for areas where agroforestry is currently not-practised or is declining, and 4/ to promote the wider adoption of appropriate agroforestry systems in Europe.

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Research needs

Research should focus on:

- Monitor forage status (productivity) of grassland, classify plant communities and track forage productivity/biomass by remote sensing for a better understanding of the relation to site conditions (weather, soil).
- Programmes of plant breeding and selection which should start by characterizing and screening entries of pasture plants coming from existing germoplasm banks (e.g. FAO, ICARDA, nationals) or from new collections or other sources of genetic variability. The evaluation of the plant material will include their characteristics of adaptation to different soil and climate conditions.
- Composition of seed mixtures for each soil/climate condition by using functional groups principle (select cvs. of productive and persistent legumes/grasses/others attending at the following characteristics: vegetative and reproductive cycles, perennially and persistency, depth of the root systems, summer or winter dormancy, drought and/or water logging resistance, pest and disease resistance, feed quality and feed intake).
- Develop a program on soil/plant microbiology, with particular emphasis on the Rhizobium/legume symbiosis and on the plant/arbuscular mycorrhiza /phosphate solubilizing bacteria, in order to enhance N fixation and phosphate availability for grasslands. As a follow up of the above, develop practical and efficient methods of producing and using inoculants.
- Viable, affordable solutions for farms relying only on mechanical weed control, i.e. development of devices for targeted mechanical weed control and reducing labour input or promotion of weed wiper, using sponges to wipe out taller growing weeds in pastures and forage crops.
- Management of legumes under grazing by pasture establishing and maintaining its persistence in both high output and low output systems, i.e. by increasing stocking rate to allow clover to persist or using goats in mixed herds of cattle and goats under moderate grazing pressures or by adapting the grazing-cutting regime in high output systems to allow an adequate proportion of shrubs/herbaceous in land.
- Increasing the potential yield and quality of grasslands through a combination of extending the grass growing season, plant breeding, use of mixtures of plant species and dynamic stocking systems.
- Develop research dealing with the use of different types of trees in grasslands as a form to reduce the climate change impact, increase growing season, quality and biodiversity.
- Provide adequate and simple tools to fertilize and amend of permanent grasslands which are understandable for farmers and link this practice to high quality products.
- Provide farmers adequate combinations of tree and shrub species, density and distribution to enhance pasture production and quality.

Innovative actions

- Knowledge transfer to farmers about management options like seed mixtures, fertilizers, amendments, weed control, grazing regime, type and density of trees in silvopastoral system by using innovative information tools that have to be developed and adapted according to local conditions.
- Provide the farmers with information about potential forage quality depending on cutting or grazing time, method of conservation, meteorology and site characteristics by means of user-friendly, low-cost, ICT-based tools.
- Promote the use of soil analysis to accurately determine the content of nutrients in the soil and their evolution with time, in order to adopt a rational plan of soil fertilization/soil amendments to adequately supply nutrient to grasslands.
- Promote the best methods of forage conservation and utilization of permanent grassland as quality hay, haylage and silage (through improved knowledge and extension) in order to embed the seasonal quality attributes of grassland resources.

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References

Dear B.S. and Roggero P.P. (2003). The present and potential role of perennial grass monocultures and mixtures with annual legumes in Italian and Southern Australian farming systems. In: Bennett S.J. (ed) New perennial legumes for sustainable agriculture. University of Western Australia Press, Crawley, Western Australia.

Finn J., Kirwan L., Connolly J., Sebastia`M.T., Helgadottir A., Baadshaug O.H., Be´ langer G., Black A., Brophy C., Collins R., Cop J., Dalmannsdòttir S., Delgado I., Elgersma A., Fothergill M., Frankow-Lindberg B., Ghesquiere A., Golinska B., Golinski P., Grieu P., Gustavsson A.M., Hőglind M., Huguenin-Elie O., Jørgensen M., Kadziuliene Z., Kurki P., Llurba R., Lunnan T., Porqueddu C., Suter M., Thumm U. and Lüscher A. (2013). Ecosystem function enhanced by combining four functional types of plant species in intensively managed grassland mixtures: a 3-year continental-scale field experiment. Journal of Applied Ecology 2013, 50, 365–375.

Franca A., Porqueddu C. and Dettori D. (2007). Evaluating new grass-legume mixtures for pasture improvement in a semi-arid environment. Grassland Science in Europe 12, 43-46.

Ghesquière M., Humphreys M.W. and Zwierzykowski Z. (2010). Festulolium. In: Boller B., Posselt U.K. and Veronesi F. (eds) Fodder Crops and Amenity Grasses, Handbook of Plant Breeding 5, Springer Science+Business Media, 293-316.

Hector, A. and Bagchi, R. (2007). Biodiversity and ecosystem multifunctionality. Nature 448, 188-190.

IPCC (2014). Climate change 2014, IPCC Fifth Assessment Synthesis Report.

Lüscher, A., Finn, J.A., Connolly, J., Sebastià, M.T., Collins,,R.P, Fothergill, M., Porqueddu, C., Brophy, C., Huguenin-Elie, O., Kirwan, L., Nyfeler, D. and Helgadóttir, A. (2008). Benefits of sward diversity for agricultural grasslands. Biodiversity 9, 29-32.

Miller, L.A., Moorby, J.M., Davies, D.R., Humphreys, M.O., Scollan, N.D. and MacRae, J.C. (2001). Increased concentration of water-soluble carbohydrate in perennial ryegrass (Lolium perenne L.). Milk production from late-lactation dairy cows. Grass and Forage Science 56 (4), 383-394.

Regulation 1307 (2014). Regulation (EU) No 1307/2013 of the European Parliament and of the Council of 17 december 2013 establishing rules for direct payments to farmers under support schemes within the framework of the common agricultural policy and repealing Council Regulation (EC) No 637/2008 and Council Regulation (EC) No 73/2009.

Rook A.J., Dumont B., Isselstein J., Osoro K., WallisDeWries M.F., Parente G. and Mills J. (2004). Matching type of livestock to desired biodiversity outcomes in pastures. A review. Biological Conservation 119, 137-150.

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