



MULTISWARD Report Summary

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Final Report Summary - MULTISWARD (Multi species swards and multi scale strategies for multifunctional grassland based ruminant production systems)

Executive Summary:

European grassland area has been significantly reduced (by 15 Mha) during the last thirty years in favour of the production of fodder maize and other annual crops and even marginal grasslands tend to be abandoned. However, the increasing environmental concerns about production systems and the European concerns about food quality and safety favour the increasing role of grassland-based ruminant systems in the future. In this context, MultiSward aimed to (i) conceive, evaluate and promote sustainable ruminant production systems based on the use of grasslands with a high level of multi-functionality through the concerted use of diverse multi-species swards, plant communities at farm and landscape levels and production systems and (ii) provide adequate evaluation tools to assess the best ways of combining high production efficiency with optimal provision of regulating and supporting ecosystem services from grasslands from farm to regional level. To reach the objectives, MultiSward developed long term experiments with controlled factors, made field measurements on networks of grasslands, assessed scenario by modelling and ensured stakeholder's involvement during the project.

Online questionnaires (2000 answers), national and international stakeholder meetings showed that the different functions of grasslands are highly recognized and appreciated, and that European grassland area is considered a valuable resource, essential for economy, environment and people.

To reinforce the competitiveness and environmental benefits of grassland-based systems, it was demonstrated that the use of sown multi-species swards combining legumes and grasses as well as shallow and deep rooting species are as productive as fertilized grasses; they produce high quality forages, allow high animal performances, and high animal output per ha. These results do not seem to be conflicting with the delivery of a range of ecosystem services.

Concerning the permanent grassland, the project identified differentiated grassland management at the farm scale as an important component of plant diversity conservation, and identified management and climate variables influencing functional diversity criteria linked to ecosystem services. Several innovations in grazing management were proposed: grazing season length can be extended with little effect on nitrate leaching in autumn; the abundance of bumblebees and butterflies can be increased by withdrawing animals for a period in summer. However, performing grassland based system requires adapted breed and/or strain of animal (dairy cows, sheep).

Different operational sets of indicators implemented at farm and/or landscape levels and applicable over the diversity of European territories and farming systems were developed. They demonstrate the contribution of grassland-based systems and management thereof to the provision of food and environmental services and the maintenance of farmland biodiversity at a European level. Several scenarios (policy options and price hypothesis) have been assessed in modelling. Extensive grassland abandonment may be prevented by area payment supporting grassland use whereas lower CAP support payment and higher commodity prices may cause less control of land use.

Active dissemination occurred during the project: an e-learning centre is available in four languages with a wiki-system; a handbook entitled "Grasslands and herbivore production in Europe and effects of common policies" published by Quae Editions is available as hard copies and free downloadable electronic version. Oral dissemination of the results was regularly performed: a stakeholder meeting held in Brussels; EGF (European Grassland Federation) meetings; and national conferences.

In conclusion, MultiSward provided and disseminated an EU-wide and multifunctional oriented overview of grassland-based ruminant production systems, opening the opportunity to define on a new basis their contribution to economic returns for farmers, biodiversity conservation and other ecosystem services. This will lead to a better consideration and acceptance of these ruminant production systems by EU citizens, consumers and farmers, and will contribute to secure the European grassland acreage.

Project Context and Objectives:

Context

Apart from food, fibre and fuel production ('provisioning' services), several important ecosystems services provided by grasslands have been identified by the Millennium Ecosystem Assessment: (i) 'regulating' services, especially carbon sequestration which might partly counteract methane emissions from ruminants; (ii) 'supporting' services such as soil formation and protection, nutrient cycling; and (iii) 'cultural' services including recreation and the aesthetic value of the landscape. Grasslands are not only a relatively cheap source of feed for ruminants, but are also increasingly being

recognised for their contribution to the conservation of biodiversity, the regulation of physical and chemical fluxes in ecosystems, the mitigation of pollution and the production of landscape amenity. The relative importance of the multiple functions provided to society by grasslands varies depending on regional contexts and grassland type. There are strong differences among European regions in terms of plant nutrients availability, and with regard to competition for land use between grassland and annual crops or forestry. There are also large differences between species-poor temporary grasslands and species-rich permanent grasslands. Further, the services provided by grasslands are strongly influenced by the type of management: extensive, species-rich and nutrient-poor systems result in less 'provisioning' services but are more effective at providing other types of services than intensive grassland-based systems.

However, despite the provision of environmental services, grassland acreage has been significantly reduced in Europe during the last thirty years (by approximately 15 M ha, i.e. 30%) in favour of the production of fodder maize and other annual crops ; even marginal grasslands tend to be abandoned, particularly in mountainous and Mediterranean areas. This was the consequence of farming systems intensification, specialization of production, price support, premium systems and farm size growth. Many farmers are reluctant towards grassland based system because management of grazing is difficult: grass growth is difficult to predict and high genetic merit cows for milk production are not well suited for these systems whereas the production of public goods is not (or poorly) remunerated by the market (price of the product) or the public policy.

New opportunities recently appeared for grassland based systems. Rising global demand for meat and milk, environmental concerns about the sustainability of intensive production systems and European concerns about food quality and safety favour the increasing role of sustainable grassland-based ruminant systems in the future. Climate change mitigation policies could support the conversion of arable land to grassland for carbon sequestration. Cross-compliance requires that farmers comply with a set of Good Agricultural and Environmental Practices, including the obligation to maintain the proportion of permanent grassland in the Agricultural Area. Farmers must also respect the Habitat, Bird and Nitrate Directives. Rural development expenditures can be a tool for supporting grassland-based systems. Less Favored Areas payments contribute significantly to the income of livestock farmers: the majority of these farmers operate in such areas and the amounts of the payments are not negligible. In the same time, farming practices can have both positive and negative externalities and too little is known about how well the different grassland management systems and their localisations perform in delivering ecosystem services. Therefore, comprehensive studies of the influence of different management strategies in different local conditions on the positive and negative externalities of the production from field to landscape level are required. This clearly stresses the importance of considering many environmental impacts and of using a multi-scale and multicriteria approach when assessing the productive and environmental performance of an agricultural production system.

The potential agronomic benefits from multi-species swards (MSS) have been recognized by the COST Action 852 but the simplicity of managing grass monocultures and the low price of mineral nitrogen have formerly inhibited the use of (MSS) for forage production. Nowadays, however, the increasing importance of improving the sustainability of agricultural production systems has translated into increased interest in the potential benefits of MSS. In relatively species-rich and nutrient-poor systems, the provision of ecosystems services is generally enhanced by species diversity. Fertile agrosystems mixed swards (grass and legume) can reduce energy consumption by replacing highly energy demanding nitrogen (N) fertilizer, by natural nitrogen fixation, whilst maintaining biomass production (COST 852). Multi-species swards may also allow the extension of the growing season as some species will be more productive at the beginning and end of the traditional grass growing season

Overall objectives and strategy

The ambitions of MultiSward are (i) to support developments and innovations to conceive, evaluate and promote new sustainable ruminant production systems using on the one hand, grasslands with a high level of multifunctionality in order to optimize the provision of environmental goods and biodiversity preservation, and on the other hand, economic efficiency and provision of quality food; (ii) to reinforce grassland research in Europe and (iii) contribute to a better understanding of the multifunctional roles of grasslands and livestock systems by European citizens, including decisions makers by an active communication. To reach this overall objective, MultiSward will

- Define the roles and utility of grassland at catchment and landscape levels from economic, agronomic and environmental perspectives and determine stakeholders' expectations with respect to multi-functionality of grassland in EU countries;
- Assess and optimize the performance of multi-species swards (MSS) in terms of plant productivity, animal nutrition and the provision of regulating and supporting services over a range of environments and determine the most appropriate mixtures according to the soil and climatic conditions;
- Design and evaluate innovations in grazing and animal management (including animal genetics) to assess the best way of combining high production efficiency, competitiveness and provision of ecosystem services;
- Provide adequate evaluation tools (models and indicators) to assess ways of combining high production efficiency with optimal provision of regulating and supporting services from grasslands at farm to regional levels;
- Identify and analyse the effects of socio-economic and policy scenarios on the future of grassland acreage and identify under which policy conditions sustainable grassland systems will become a viable option for farmers compared to crop-based systems;
- Disseminate knowledge to key stakeholders (farmers and extension services, policy-makers, water agencies, national offices for registration and seed control, feed industry, milk and meat food chains, consumers, nature conservation groups, etc.) through a participatory framework that will allow exchanges between researchers and key stakeholders and increase awareness on the advantages of grassland-based systems.

MultiSward considers provisioning services (food and feed production mainly), regulating services (climate regulation, water quality protection) and supporting services such as nitrogen fixation, nutrient cycling and soil humus formation provided by ruminant production systems. Cultural services are not investigated in details. The strategy of MultiSward is to:

- Develop a concerted use of diverse multi-species swards, plant communities at farm and landscape levels and production systems;
- Cover the 5 main biogeographical regions (Atlantic, Continental, Alpine, Mediterranean, Boreal) and consider high inputs and low inputs systems, productive grassland and nutrient poor systems occurring in Europe, thus covering a large array of ecosystem services
- Develop an innovative, holistic and multi-scale approach combining interactive stakeholders consultation, a network of experiments (including a common multi-sites experiment) and on-farm-survey and development of indicators systems and models for simulating scenario;
- Produce recommendations and tools for different groups of stakeholders in order to maintain competitive grassland-based ruminant production systems and to secure optimal acreage and utilization of grasslands in Europe.;
- Develop a participatory framework for knowledge dissemination to key stakeholders.

Specific objective of the work packages (WP)

WP1 defines the roles of grasslands, identifies stakeholder expectations and secures their participation in the project. This allows to precisely define what grassland-based farming systems should deliver according to stakeholders. WP1 objectives are to (i) assess the importance, roles and utility of grasslands in Europe at the catchment and landscape levels from economic, agronomic and environmental perspectives and (ii) determine stakeholder requirements and expectations with respect to multi-functionality of grasslands within Europe.

WP2 investigates the feed provisioning aspects of multi-species sown swards and permanent grassland in comparison with monocultures in terms of the relationships between sward diversity, sward dynamics, agronomic performances and nutritional value. Species diversity is a controlled factor. Results from COST Action 852, showed that strong yield benefits of mixing grasses and legumes could be achieved and these benefits were found to occur with mixtures of only four species. However the results are limited to cutting managements and to date, few grazing trials have been conducted to determine the livestock productivity response to plant diversity in pastures. The Common Experiment carried out by MultiSward partners in WP2 addresses this knowledge gap. In addition, factors contributing to yield stability in MSS are analysed using molecular techniques to identify the basic mechanisms underlying inter- and intra-specific competition. Yield stability and the effect of species dynamics on the nutritive content of forage are key issues affecting the agronomic use of MSS. WP2 objectives are to (i) measure biomass productivity and species dynamics and their relationship with sward nutritive quality; (ii) quantify animal performance, product quality and methane emissions from indoor-fed animals and animals grazing MSS compared with pure grass stands, (iii) carry out molecular analyses of genetic change over time in populations of pasture species in contrasting competitive environments and under different defoliation regimes and (iv) to test the efficacy of plant growth models to describe the behaviour of MSS.

WP3 performs field measurements on the effects of multi-specific swards on the delivery of ecosystem services, assesses the effects of management on diversity criteria, and develops indicator-based evaluation tools. There are strong interactions with WP2 (same network of experiments). Optimization of grassland management faces the difficulty of trade-offs that exist between productivity and other ecosystem services, as well as between different impact categories. This highlights the importance of considering many environmental impacts when assessing the options for improved eco-efficiency of grassland-based production systems. Several systems of agri-environmental indicators have been designed for the evaluation at different scales of sustainability in agro-ecosystems. Because the effects of the species diversity of the swards on the environmental roles of agriculturally used grasslands were largely unknown, the indicator systems developed before MultiSward are mostly insensitive to this factor. The objectives of WP3 are to (i) Assess the potential for optimising the environmental roles of grassland through the concerted use of plant species diversity at the field level, (ii) Assess the effect of grassland management on grassland biodiversity from the field to the landscape level, (iii) Provide an indicator-based evaluation tool for assessing the environmental roles of grassland at the field level, (iv) Evaluate the indicators and synthesize the interactions between grassland management, diversity and environmental services at the local level, and (v) provide an indicator based evaluation tool for assessing the environmental roles of grassland at the regional level.

WP4 designs and evaluates innovations in grazing and animal management to enhance the sustainability and competitiveness of grassland-based ruminant production system. Advancements in grazing management have shown opportunities to extend the grazing season in early spring and late autumn but the influence of extending the grazing season on nitrate leaching and soil compaction is not documented and requires further investigation. Similarly, the manipulation of grazing rotation length and sward management to increase biodiversity is not yet well documented. Successful grazing systems also clearly require the most adapted animal genetics (breeds or strains achieving large intake of forage, fertile and healthy, able to walk long distances and high survivability). Dual-purpose dairy cow breeds and crossing the Holstein-Friesian with an alternative dairy breed sire are tested as well as different breeds of sheep. The objectives of WP4 are to (i) undertake a comprehensive literature review identifying aspects of overall sustainability and producing a list of attributes/indicators to analyse production systems, (ii) conceive, examine and evaluate innovative farming systems addressing the trade-off between productivity, environmental and social services within contrasted grassland-based systems, (iii) compare the suitability of strains/breeds for pasture based systems in terms of grazing performance, product quality, health and welfare and (v) to analyse aspects (including production, economic, and GHG emissions) of grass based milk production systems using modelling.

WP5 identifies existing socio-economic and political driving forces supporting grassland development or inducing grassland replacement by annual crops, and their effects at farm and region levels in order to help policy makers to produce new instruments by providing them with scientific expertise and scenario evaluation. The scenarios are defined notably on the basis of the results of the others WPs and selected for their possible effects on the grassland acreage in the future. Grassland is subject to multiples driving forces and the final effect of these interactions are examined on the basis of scenarios by using models and sets of indicators in order to help policy makers to design future programmes. The objectives of WP5 are to (i) assess the competitiveness of grassland-based systems compared to other feed production systems at farm level and determine in which structural, agronomical and social conditions grassland-based systems can be competitive, (ii) evaluate scenario defined on the basis of stakeholders and expert consultations on economic and environmental outputs and (iii) evaluate at a regional level the range of ecosystems services provided by grasslands and the effect of several ruminant production systems on the environment using a complete set of indicators

WP6 improves the exchange of information and experience and disseminates MultiSward achievements and knowledge to the socio-economic stakeholders, especially farmers, rural extension services, other rural actors, teachers and policy-makers and to the scientific community in order to promote innovations in agriculture and animal husbandry. Next to the top-down dissemination which is commonly implemented in research projects, the project aimed at improving the exchange of information and experience with the various stakeholders. In a classical way, information is compiled into paper articles/books. Because this would strongly reduce the potential dissemination it was decided to prioritize dissemination through electronic freely available documents. This represents a new paradigm of knowledge dissemination in European projects. The objectives of WP6 are to (i) present achievements of MultiSward in many meetings of national grasslands societies, during international conferences where special sessions were devoted to MultiSward and to key stakeholders and, beyond these classical ways of dissemination, (ii) produce a synthesis of the state of the art of grasslands in Europe through an electronic book freely available in many platforms under an e-pub book and/or a pdf file, (iii) set up an e-learning centre in several languages, based upon a wiki system that aims to disseminate knowledge in many European countries. At the end of the project, the e-learning centre is split into four independent sites, each one being transferred to national grasslands societies that will be in charge of its future, i.e. maintenance and enrichment.

Project Results:

1. Roles and utility of grassland and stakeholder's requirements and expectations with respect to multi-functionality of grassland in EU countries (WP1, WP5, WP6)

In a first step MultiSward has compiled an inventory of grassland in Europe, the relevant acreages and their evolution, the driving forces that were at work in these changes, the multiple functions of grassland that benefit humans and the expectation of stakeholders with respect to multi-functionality of grasslands within Europe. This provides an up to date picture of grassland in Europe and a handbook presenting this overview in a comprehensive way. The presentation of case studies illustrating the wide range of climate and soil conditions under which grasslands are cultivated in Europe and 16 farmer's interviews covering the diversity of the animal production in Europe and the range of environmental conditions that the farmers have to deal with provide a real added value to the book.

1a. Evolution of grassland acreage and socio-economic and political driving forces

Among the most significant results it appears that:

- The European grassland area has been significantly reduced during the last 30 years but this variation is not yet well documented. The estimation of losses of the permanent grassland area is difficult and estimates vary according to the sources of information (Eurostat, FAO, national statistics). Harmonisation between data basis is required.
- Some economic forces strongly encourage the decrease of grassland area. The implementation of the milk quotas in 1984 has supported milk price by controlling the production in the EU and together with the low price of cereals has encouraged dairy to produce more milk per cow and to reduce the number of dairy cows and the need for forage. This trend was reinforced by breeding progress of dairy breeds.
- Some sociological forces strongly induced the replacement of grasslands by annual crops. A constant reduction in beef and sheep meat consumption of European citizens in favour of pig and poultry meat has been observed. For instance between 1995 and 2008 in the EU-27, cattle meat production decreased by about 9% while pig meat increased by 17%. If less ruminant meat is consumed and the grassland area does not change, an extensification of grassland management is possible, but it is more likely that a higher demand for monogastric meat will induce the replacement of a part of the grassland area by crops or other land uses.
- Several Common Agricultural Policy (CAP) instruments have been of special importance for the evolution of grassland area. Before the CAP reform of 2003, a higher proportion of the budget (especially from Pillar 1) was spent per ha of arable land compared to grassland and in Field crop specialist holdings compared to Grazing livestock specialist holdings. After the reform of 2003, the negative effects of Pillar 1 subsidies on the grassland area were reduced. Premiums were no more linked with crop or animal types but to the eligible area. That suppressed the 'maize premium' that encouraged farmers to use this forage crop at the expense of grasslands. The use of grasslands was also not anymore indirectly supported through animal premiums but directly through area payments (the system was though applied with a certain amount of flexibility among Member States according to the re-nationalisation principle). The cross-compliance rule on the protection of permanent grassland introduced after the mid-term review intended to reduce to some extent further conversion of permanent grassland into arable land. The reform changed thus radically the context and the way a farmer can think about his forage system. The Nitrate Directive had a significant influence on

farm structures and practices of intensive livestock systems by regulating the stocking rate and the management of nitrogen.

1b. Stakeholder requirements and expectations with respect to multi-functionality of grasslands within Europe

Active participation of stakeholders was a key objective of the MultiSward project. On-line questionnaire (developed in eight languages, 1959 valid responses), national and international meetings among different stakeholders (primary producer, policy maker, research and advice, NGO's for nature conservation and for protection of the environment, industries and education) and different regions in Europe provided insights into the appreciation of the current and future functions of grasslands in Europe.

The results show that many individual functions of grasslands are highly recognized and appreciated by all relevant stakeholder groups even if the relative importance of the different services may vary according to the group of stakeholders. All aspects of sustainability were considered to be important and the questionnaire allowed some quantification. When people were asked to divide 10 points over economic, ecological and social aspects of sustainability, on average, economy was valued the highest (3.7) followed by ecology (3.4) and social aspects (2.9). The differences remain modest and these means also show that all aspects of sustainability were considered to be important (economic aspects, ecological aspects and social aspects). Stakeholders were also asked to value different functions of grasslands. An impressive number of important functions of grasslands were found. Functions for which more than 50% of the respondents scored either 4 or 5 (important or very important) were found in all groups of ecosystem services:

- In the group "provisioning services" the stakeholders ranked the following functions high (more than 50% ranked 4 or 5): high quality forage, dairy cow milk production, low cost animal feed, nutritional quality of animal products for human consumption, beef meat production, global food production and region of origin of animal products. Less important functions (more than 50% ranked 1 or 2) were production of plant fibre, biomass for energy production and small ruminant production;
- In the group "regulating services" biodiversity, conservation of the quality of ecosystems and water catchment were ranked high, while fire control and avalanche control were ranked low probably because the latter services are only relevant in specific regions;
- In the group "supporting services" of grassland there were no services that were ranked low. The importance of the function grazing was strongly recognized. Grazing in fact ranked the highest of all ecosystem services. For the supporting services also animal health, animal welfare, conservation of soil structure and fertility, supply of feed protein at farm level, competitiveness of farming systems and N fixation via legumes were ranked high;
- Stakeholders had a positive perception of the role of grasslands in many "cultural services", e.g. in the beauty of the landscape and in animal production systems, followed by rural development and maintaining populations in rural areas. Supporting horses for equestrian sport and recreation was ranked low and does therefore not appear to be a major priority.

2. Assessment and optimisation of the performances of multi-species swards (MSS) in terms of provisioning, regulating and supporting services (WP2, WP3)

2a. Effect of plant diversity on short and long term herbage production

The objectives of MultiSward were to assess the effects of diversity on biomass productivity, yield stability and weed content in MSS and provision of ecosystem services. Dynamics of species abundance and relationships between abundance and functional compatibility in MSS were analysed. It was hypothesized that using grass/legume mixtures comprising a small number of strategically chosen species for forage production would be a viable option for achieving sustainable intensification of grassland-based agricultural production, and a decrease in the environmental burden of forage production through a reduction of agricultural inputs. Four forage species corresponding to four different 'functional groups' were used as follows: Nf = non-N fixing, Sr = shallow rooting; Fi = N-fixing; Dr = deep rooting. Mixtures of the following species were established: perennial ryegrass (Nf-Sr), *Festuca arundinacea* or Chicory (Nf-Dr), white clover (Fi-Sr) and red clover (Fi-Dr).

The results generally demonstrated considerable overlap in yield between the various swards categories compared to pure grasses with similar level of N fertilisation and that there was no detriment to dry matter (DM) yield in legume-based MSS receiving medium level of nitrogen fertilizer compared to grass monocultures receiving high inputs of external nitrogen fertilizer. Increased use of MSS therefore potentially represents a substantial economic and environmental saving when the various costs associated with the use of nitrogen fertilizer are considered. Over all time scales significant changes in the contribution of sown species to total biomass in mixtures occurred over time in MSS. This illustrates the complexity of species dynamics in MSS: understanding them requires knowledge of the growth patterns of species over time, how these may be modified by co-occurring species, variation in the responses of genotypes within species, and the effects of genetic change over time within genomes.

A novel aspect of the Common Experiment (CE) was the defoliation management ('grazing vs. cutting') comparison between biomass production in MSS and grass monocultures. We observed different sward responses to defoliation management. With cattle and dairy cows, there were no clear effects on sward yield of cutting vs. grazing and no interactions between defoliation management and sward type. With sheep, grazing had no effect on sward yield on grass-based swards but reduced it on legume-based swards compared with the cutting management. Thus, sheep

grazing appeared to have a direct and detrimental effect on the legume component of MSS and this result supports the hypothesis that selection of different species or sward types by grazing sheep can have a large effect on the yield, stability and composition of MSS, but that the identity of the grazing animal is the key determinant.

Some genetic analysis were undertaken to understand the genetic basis of plant-plant interactions in MSS in terms of persistence and competitive ability, so as to improve the predictability of species dynamics in mixtures.

- The effect of cutting vs. grazing on genetic change in MSS over time were analyzed for ryegrass, white and red clover over three years using a number of neutral SSR markers representing candidate genes related to stress responses. The ryegrass and clover population had a slightly higher heterozygosity at the beginning than at the end of the 3 years period but the differences remained small. Less than 5% of the molecular variance could be attributed to among-population variation, 90% or more are due to within-individuals and 5 to 15% to among-individuals variation, these proportions varying with the species. There was no evidence of genetic change in response to defoliation management.
- The genetic shifts in grass/legume mixtures composed of different cultivars were investigated over 3 years using a set of SSR markers. The study revealed a very high level of polymorphism in all the varieties included in the study. In both species, heterozygosity levels were similar in the 'start' and 'end' sampling points, confirming that no large reductions in diversity had taken place over three years. Genetic shifts over the sampling period were generally small. Over time, perennial ryegrass populations became differentiated from each other in a predictable way but the behaviour of red clover populations was more unpredictable, indicating that local and/or random selection effects played a more relevant role for this species. SNP polymorphisms in candidate genes for branching/tillering were identified in perennial ryegrass and in red clover.

2b. Effect of plant diversity on herbage intake and digestive efficiency in ruminant

MultiSward entails investigations of animal responses to complex swards to better understand the effects of interactions that can occur between plants on digestion and intake. Experiments were conducted with ruminants fed indoors ad libitum to estimate the voluntary dry matter intake and in grazing situation. To study the associative effects between plants species, binary mixtures of forages in controlled proportions were used in indoors trials. The results clearly showed that herbage intake, in sheep, cattle and dairy cows was positively related to diet complexity either in the case of fresh forages or silages, in stall-fed or in grazing animals. Greater pasture intake on MSS was observed in most trials and may be related to the fact that a mixture of several forages could stimulate the motivation to eat and to the higher voluntary intake of legumes, white clover in particular:

- In sheep fed indoors, the responses in experiment using binary mixtures of cocksfoot and red clover silages or fresh ryegrass and chicory on DM intake were quadratic, the optimums being observed with the proportions 50-50%, and the percentage differences between the values measured for the plant combinations and the balanced median values from pure forages were +9.5% (silage) and +5.6% (fresh forage). These synergies did not seem to be due to a more effective digestion, as positive quadratic effects were not observed on DM digestibility. The synergies were not found when mixtures of fresh ryegrass and white clover were tested. For the mixture of cocksfoot and red clover, a quadratic effect was observed on daily eating rate suggesting a greater motivation to eat when the forages were supplied in 50:50 mixtures thus indicating that the diversity in the ration stimulated animal intake.
- At grazing, an experiment carried out over two years, as part of the common experiment clearly demonstrates advantage of MSS on a per cow basis for pasture DM intake and milk yield. Similar results were obtained for cattle (Agroscope-Tanikon) when comparing rye grass and the mixture of four species.

In the three sheep experiments, enteric methane emission per unit of feed intake tended to be lower when pure legumes were fed compared to grasses but the differences remains small (10%) and are negligible when considering grass/white clover with 10 to 50% clover in the mixture. It is noteworthy that methane production linearly decreases when increasing the proportion of chicory in a mixture of ryegrass and chicory (-2%/10% increase of chicory). The effects of ryegrass-only and ryegrass/white clover mixtures on enteric methane emission were also investigated for grazing dairy cows. Methane emission per unit of feed intake was lower for the grass/white clover cows compared to the grass-only cows. These results can be attributed to two factors: 1) the differences between grass and clover or chicory during the digestion process (these two latter species having a very low content of fibre) and 2) the increased DMI that the legumes can promote when added to grass-only pasture.

The effect of ryegrass-only and ryegrass/white clover mixtures on ruminal fermentation pattern was also investigated. Dairy cows that grazed mixed swards had a greater proportion of rumen VFA isoacids and ammonia in relation to the higher N content of forage. Rumen pH was higher for the cows foraging on mixed swards compared with those offered perennial rye grass and these responses were greatest in autumn. This was partly due to an increase in clover content, but also to a decrease in perennial ryegrass quality with advancing maturity resulting from a longer regrowth interval in autumn.

The effects on N partitioning in dairy cows of high sugar vs. standard perennial ryegrass varieties with and without white clover were analysed. The excretion of N in urine from cows fed the grass/clover mixtures was approximately 2.5 times higher than that from cows fed grass alone whatever the ryegrass varieties. This was due to considerably higher dietary concentrations of N from the white clover forage, and correspondingly lower dietary concentrations of sugar. Increasing the N concentration of the cows' diet through the incorporation of white clover increased the rates of urine N excretion thus confirming previous results reported in literature.

2c. Potential for optimising the environmental roles of grassland through the concerted use of plant species diversity at the field level

Field experiments were conducted to assess the impact of multi-species swards in intensive forage production systems on the delivery of regulating and supporting services. The results showed that the use of legume-based multi-species swards to achieve productive grasslands and partially replace nitrogen (N) fertilizer by symbiotic N₂ fixation can help improve the delivery of some supporting and regulating services of grassland-based forage production systems without increasing the risks for negative environmental impacts. They also showed that the optimisation of the botanical composition of the swards for improving the environmental roles of grassland at the field level should target a balanced relative abundance of productive legumes and grasses, as well as of deep- and shallow-rooting species.

- Direct N₂O emission from symbiotic N₂ fixation was found to be negligible and considering the quantity of N₂O emitted per unit of forage produced, grass-legume mixtures performed as well as or better than grass monocultures. With respect to the CH₄ emissions from lactating cows, no very significant effect of grass-legume mixtures could be observed under grazing (see 2b). When considering CH₄ and N₂O emissions in the estimation of the net GHG balance, the sink activity of these ecosystems remained relatively low. On a product-related basis, grass-legume mixtures therefore have a positive to neutral effect on the field emissions of GHG, and the reduction of GHG emission from upstream processes thanks to the lower requirements of mineral N fertilizers can thus be fully accounted as an advantage of multi-species swards as compared to grass monocultures.

- The use of legume-based multi-species swards showed clear advantages compared to fertilizer-based grass monocultures with respect to an efficient use of N. The results show that moderately fertilized pure swards of the shallow rooting perennial ryegrass swards do not guarantee a low residual mineral N in the soil (N_{min}) during winter, and that mixtures with the deep-rooting red clover as N-fixing component perform better than those with the shallow rooting white clover with respect to residual N_{min} in the soil. Finally, multi-species swards combining both N-fixing and non-fixing species and including a deep-rooting species performed as well in terms of residual mineral N in the soil (N_{min}) and better in terms of N_{min}/yield ratio (productive function) as compared with pure perennial ryegrass swards. Under cutting, grass-legume mixtures did not show any elevated risk for nitrate leaching as compared to pure grass swards. Under grazing, the grass-legume mixtures showed a slightly higher risk of nitrate leaching than the fertilizer based pure grass system only at one of the two experimental sites, and within this site only at two of the four studied points in time.

- Combining shallow- and deep-rooting species nevertheless proved interesting for the use of the soil profile by the plant community. Some evidence for temporal niche differentiation in N uptake from fertilizer was found between perennial ryegrass (spring species) and red clover and chicory (summer species). Mixing species with different temporal patterns of nutrient uptake might therefore contribute to a high nutrient capture and consequent high biomass production in multi-species swards.

- The effect of plant diversity on faunistic diversity was positive or neutral depending on the taxa. While the nectar-dependent butterflies were more abundant and species-rich on the more diverse swards, grasshoppers and earthworms did not reflect this pattern. We therefore conclude that grassland plant diversity can be considered as positive for the conservation of faunistic diversity as a whole, but that the promotion of grassland plant diversity has to be complemented with further specific measures to effectively promote a large range of taxa.

- Calculation with model forage production systems showed that using symbiotic N₂ fixation by legumes to reduce the need for N fertilization of the grassland is positive with respect to the demand for non-renewable energy resources, even if the establishment of legume rich mixtures may need some machinery operations.

In conclusion, MultiSward clearly shows that increased biomass productivity of grassland through the concerted use of plant diversity does not conflict with the delivery of a broad range of services. Increased use of MSS therefore potentially represents a substantial economic and environmental saving when various costs of nitrogen fertilizers are considered.

2d. Effect of grassland management on grassland biodiversity from the field to the landscape level

In ruminant production systems located in grassland dominated, landscapes diversity conservation is a key issue. The beneficial ecosystem services provided by grassland partly depend on biodiversity. A scientific innovation of MultiSward was to test the relevance of the functional approach for understanding the effects of management and climate on grassland diversity in order to assess the possibilities of increasing biodiversity at local (field, farm) level using large dataset of permanent grasslands covering a large range of soil and climatic conditions in Europe.

At the plot scale, MultiSward assessed the effects of management and climate on functional diversity criteria linked to ecosystem services considering plant species richness and the community-weighted value of Specific Leaf Area (SLA), Leaf Nitrogen Content (LNC) and of the onset of flowering as relevant variables because they are involved in the delivery of ecosystem services such as forage quantity and quality, or pollination. More than 60% of the variance in species richness could be explained by the surveyed climatic and management variables. Plant species richness and the onset of flowering increased with altitude, while the community-weighted mean of SLA and LNC decreased with altitude. The climatic variables generally influenced species richness more than management variables but different management variables affected species richness; total N input and intensity of defoliation being identified as the most important variables while the type of utilisation (grazing, mowing) has a weaker effect. Both defoliation intensity and N inputs had positive effects on SLA and LNC and a negative effect on the onset of flowering. The originality of the present study was to show that the effect of management variables differed along the climatic gradient. The intensity of defoliation appeared as a main lever of the within-plot species richness (alpha diversity), within the regions with a rather cold climate, but not within the regions with a warmer one. This shows that strategies targeting an increase in within-plot species richness by modifying management practices need to be developed at the scale of small regions.

At the farm scale, the results show that most of the richness in grassland plant species is due to the between-plot diversity (beta-diversity) among grasslands. As this beta-diversity is large within all types of management of permanent grasslands, farms with many plots always have much larger species richness at the farm scale than the average alpha-diversity of their plots. Heterogeneity between grasslands therefore proved very important for plant species richness at the farm level. The results further indicate that farms managing grasslands located on the slopes of the valley sides, i.e. located in a more difficult situation from a management point of view (more labour per yield unit), shelter more plant species than farms concentrating their activity on the bottom of the valley. The estimated total species richness on model farms managing both intensive and extensive grasslands on both the bottom and the sides of the valley was as high as the estimated species richness on the same number of extensively managed grasslands on the valley sides.

At the landscape level, MultiSward investigated how agricultural management (grazing intensity and abandonment) and habitat fragmentation affects the genetic diversity of the field scabious (*Knautia arvensis* L.) which is a clonal herb widely distributed in Europe. In grasslands with no livestock grazing, *Knautia arvensis* displayed high levels of clonal reproduction. These populations had the highest population growth rates among the populations included in the study. High grazing pressure had a positive effect on sexual reproduction compared to intermediate grazing pressure and no grazing. The results indicate that land abandonment have time delayed effects on population viability in *Knautia arvensis*.

In conclusion, promoting heterogeneity thanks to a differentiated grassland management at the farm scale appears to be an important component of diversity conservation in ruminant production systems located in grassland dominated landscapes. Such a strategy should mainly consider supporting unfrequently mown grasslands receiving no or little nutrients and situated in less favourable locations, as well as extensively grazed grasslands.

2e. Interactions between grassland management, diversity and environmental services at the local level

MultiSward had developed a set of indicators based on decision trees for assessing the effect of grassland management on fauna diversity (see 4c). The first results obtained on fauna biodiversity at plot level reveal the usefulness of including plant diversity and simple management inputs to improve the environmental evaluation of grassland based systems. Plant species richness appeared to have a direct and positive effect on butterfly and moth diversity, and on grasshopper species richness. Bumblebee abundance was also positively related to legume abundance and the abundance of erected growth-form plants had a major effect on the diversity of web-building spiders. Finally, it is noteworthy that the abundance of grasses strongly influenced earthworm abundance, which suggests that earthworms might be the only group that would not take advantage of an increase in sward diversity. With biodiversity indicators developed in MultiSward, it seems possible to assess the potential value of grasslands for the species richness of butterflies, bumblebees, grasshoppers and soil dwelling spiders. For all these taxa grassland plant diversity and an adequate management can preserve a high level of biodiversity. Because abundance is more sensitive to various factors than species richness, the validation of indicators assessing abundance was less successful, except for butterflies. Overall, validation of abundance decision trees would benefit from more datasets recorded over successive years.

3. Innovations in grazing and animal management to increase competitiveness and environmental benefits of grassland based systems (WP4, WP2).

3a. Innovations in grazing and sward management

MultiSward assessed the usefulness of plant diversity on animal and system performances in intensive dairy systems and on more extensive systems.

- Using combinations of grasses and two legumes compared to a single monoculture sward of perennial ryegrass increased milk production per hectare over 13 growths on two consecutive years (+ 1 600 kg / ha with MSS) although the level of output per ha on pure ryegrass is already very high (14 000 kg/ha). Advantages of MSS on dairy cow production on a per ha basis are mainly due to an improved per cow production and intake (see 2b), and to a lesser extent to an increased number grazing days per ha.
- On low productive grassland, a rotational grazing experiment was conducted over five years using sheep and cattle in mono or mixed grazing of swards differing in diversity (6.9 vs.10.3 species/m²). Lamb production was slightly enhanced on the diverse swards and this effect was consistent over time whereas calf performance was unaffected by sward type. Lamb growth was further improved by mixed grazing. These results suggest that mixed, rotational grazing of cattle and sheep on phytodiverse agricultural swards is particularly appropriate to enhance lamb production (mixed grazing: + 17%; diverse swards: + 12%) without having any disadvantages for calf performance.

Advancements in grazing management have shown opportunities to extend the grazing season in early spring and late autumn in intensive dairy systems. We showed that extending the grazing season during autumn and winter is also possible on semi-natural lowland pastures in Poland in a suckler cow system despite some large variation of forage yield and animal intake between years. Paddocks were grazed in August and then closed until grazing in late October, November or December by 5 cows (Angus and Angus x Limousin; BW 460 to 520 kg). Herbage intake decrease during the season and was influenced by weather conditions. Good availability of herbage and favourable grazing conditions in November 2011 resulted in the highest sward intake during the experiment (11 kg DM/cow/day) while the lowest sward intake was recorded in November 2012 (5.6 kg DM/cow/day).

MultiSward also evaluated the risk of nitrate leaching and the possibilities to mitigate nitrate leaching in intensive dairy systems.

- On productive grassland, late grazing can increase nitrate leaching and soil compaction. In an experiment comparing nine grazing season lengths in Ireland at a same stocking rate, Nitrate concentrations to 1 m were affected by management. The control treatment (no grazing) had the lowest concentrations, the grazing only management had the highest, and paddocks that were grazed and had silage harvested from them had lower concentrations than the grazing only. Turning cows out on 1 February had numerically but not significantly lower kg of nitrate leached/ha to 1 m in the soil than later turnout (1 March). Nitrate leached/ha to 1 m in the soil was similar for the three autumn housing dates (10 October, 25 October or 10 November). In another experiment conducted in Belgium, the evolution of soil nitrate content in the period 1 September - 15 November was not dependent on the grassland management - cutting instead of grazing in autumn had the same effect on the nitrate content in the soil profile. However there was high variability in soil nitrate content on 1 September within pastures intensively grazed during the growing season.

- For reducing the risk of nitrate leaching restricted access time to pasture in autumn could be an option by reducing animal restitutions on the plots and consequently the risks of nitrate leaching without affecting animal performances as we showed in an experiment comparing full time access to pasture (22 hours) or restricted access time (two 5-h periods or two 3-h periods). Treatment had no effect on animal performances (milk solid yield (1.15 kg/day), body condition score (2.66), and herbage intake (15 kg/day)).

For upland pastures one of the challenges is to manage high level of biodiversity while optimizing the use of grassland for animal production. An 'ecological rotation' (ER) strategy (taking the animals away from one rotational subplot during the main flowering period to decrease the stocking density locally, thereby favouring flowering intensity) was compared with continuous grazing (CG) under cattle and sheep. Cattle grazed plots had a larger flowering cover than sheep grazed plots and cattle grazing lead to a higher butterfly and bumblebee abundance and higher species richness than sheep grazing. Ecological rotation with sheep allowed better flowering cover than CG management; no difference was found in cattle grazed plots. Managing the ER with cattle instead of sheep allowed an increase of 3.5 butterflies per transect, 1.2 butterfly species per transect, 0.9 bumblebees and 0.6 bumblebee species. Results are not clear for ground beetles abundance and species richness probably because ground beetles did not depend of flowering cover.

The organoleptic qualities of cheeses are affected by dairy cows management in uplands pastures. Compared to a classical system, a more extensive system (lower stocking rate and mineral fertilizer, no concentrates, long grassland rotation length, long cow dry period) gave cheeses with a lower yellow coloration linked to a less leafy sward that could lead to a lower β -carotene content of grass and cheeses) and were characterized by a less firm and more melting texture which was related to the higher fat and higher fat to protein ratio in milk. The odour of cheeses made with raw milk was also more intense.

3b. Animal characteristics and management

Apart from grassland management, the most profitable genotype or breed is a key factor to return the highest profit per unit of the most limiting input. Long term experiments were conducted to evaluate genotype x management interaction and modelling data from these long term grassland based dairy cow production systems allowed a more holistic evaluation of the systems, including production, some economic and environmental evaluation.

INRA compared Normande (No), which is a dual purpose breed, with Holstein-Friesian (Ho) on High and Low input feed systems. The reproductive performances were highly altered for the Ho cow with low gestation rate especially in the Low feeding group. In contrast the No cow does not seem to be sensitive to feeding level. On average the Ho breed had the lowest carbon footprint of milk. However, the relative difference between Ho and No breeds' carbon footprints of milk varied from 4 to 8%, depending on allocation method. This can be explained by differences between breeds for surplus calves and culled cows prices, GHG emissions from the replacement herd and the total energy required for producing milk and meat. Finally the high reactivity of the milk production in Holstein cows, which does not limit the body condition loss as well as the degradation of the reproduction performance, makes the Holstein cow incompatible with severe and strict management such as the herbage system with low concentrate input and compact spring calving. On the contrary the dual purpose breed appears more flexible and better adapted to low input systems based on the maximisation of grassland use for milk production.

In Ireland, the imminent removal of EU milk quotas will result in land becoming the most limiting resource. In this context, the biological efficiency of three genotypes (Jersey, Holstein-Friesian and Jersey x Holstein-Friesian (F1)) were compared across three grassland-based systems differing by the stocking rate. Milk solids per hectare were not affected by treatments. With a fixed land base, JxHo can offer immediate substantial improvements to farm profit and moderately mitigate the carbon footprint of milk. The results highlight that losses resulting from reduced cull cow and male calf value of JxHo cows compared to Ho cows are clearly overshadowed by the overall performance of the JxHo.

The suitability of Norwegian breed (NR) was studied in Ireland and Norway. The NR milk production capacity is only slightly lower than that of Ho (500 kg/lactation). Results from the NR crossbreeding study indicated that HoxNR dairy cows were capable of production levels per cow at least similar to their Ho contemporaries on low cost systems and can offer immediate and substantial improvements in fertility and survival (e.g. 6-week in-calf rate was over 10 percentage units greater for HoxNR) but little influence on the carbon footprint of milk was recorded. Because NR is selected for growth rate, the calves are well suited for beef production. Feed conversion ratio was higher for NR than Ho animals in the steer only dataset, possibly reflecting the higher final body weight of NR steers, and the forage only

diet whereas Ho animals were fed diets with higher proportions of concentrate.

Concerning meat production, the efficiency of lamb production of four sheep breeds was examined in continuous grazing conditions on lowland pasture in Poland. The results show that Romanov sheep breed had the highest daily live weight gain during the grazing season whereas lamb live weight gain of white-headed meat sheep and Blanc du Massif Central sheep was quite lower. This clearly shows that local sheep breeds are well suited for performing systems.

4. Development of adequate tools to assess the performances of grassland (WP2, WP3, WP4, WP5)

4a. model to predict grassland growth

The objective was to propose a simulation model able to cope with a wide range of management practices, weather and soil conditions. The Vege-SEBIEN model which was developed for diverse grassland for an upland region in France to simulate grass growth was adapted for lowland and more intensive systems with more frequent cuts. The Model was adapted for Irish conditions using an optimization technique in association with Moorepark meteorological and grass growth data. Several parameters were changed: nutrition index, water holding capacity (WHC), initial biomasses, bulk densities, temperature thresholds, parameters related to grass plant leaves, senescence parameters, abscission and the seasonal effect parameters. The adapted Vege-SEBIEN model has proved its capacity to simulate primary sward production over a wide range of situations, namely for permanent pastures in mountain area with continental climate and for intensively managed pure grasses sward in the South of Ireland with Atlantic climate. Improvements were achieved with changes on the parameters used by the model, thus making the adaptation possible for other locations. However these adaptations require local calibration of several parameters.

4b. Whole farm models to simulate performances of grassland based systems

The use of whole farm simulation models makes it possible to study the behaviour of a large range of virtual systems, providing dynamic information on many variables difficult to measure for technical and economic reasons. A number of models were developed within the MultiSward consortium (e.g. DairyWise, MELODIE, Moorepark Dairy Systems Model (MDSM)). An analysis of the concepts, structure, capabilities and interface of the different models was carried out and revealed that the objectives, concepts, structure, capabilities and Interface of the models are very different and that each model has some strong and weak points. Moreover, models are not easily transferable from one country to another as they are designed for local dairy systems and use locally specified parameters. Because MDSM is built to use experimental data as inputs, it is concluded that using the MDSM whole farm simulation modelling with data from long term grassland based dairy cow production systems will allow a more holistic evaluation of the systems including production, some economic and some environmental evaluation. MDSM is a stochastic budgetary simulation model of a dairy farm. The model is formulated in an Excel spreadsheet and simulates over a 12 month period, or over a number of years. MDSM was upgraded during the MultiSward project to calculate all known GHG emissions from dairy production using a cradle to farm-gate attributional LCA sub-model. MDSM provides input data (e.g. animal inventory, feed intakes etc.) for the GHG sub-model which quantifies on- and off-farm GHG sources (e.g. fertilizer, pesticide and fuel manufacture) associated with milk production up to the farm gate. The effect of including (or not) carbon sequestration under grassland was also considered.

4c. Indicator-based evaluation tool for assessing the use of multispecies sward on fauna biodiversity at the field level

An integrated tool that evaluates the impacts of grassland management on fauna biodiversity conservation, based on simple and easily accessible input variables describing management and sward composition obtained from simple interviews with farmers and botanical surveys was developed. Six taxa were selected due to their contrasting biological requirements and key biological functions, e.g. pollination (honey bees, bumblebees), pest control (spiders), preservation of soil fertility (earthworms) and spatial distributions in the grassland (endogeic - living underground), epigeic - living in the grass layer, exogeic - mostly flying). The methodology combines multi-criteria decision trees with fuzzy logic partitioning, allowing to deal with different types of information (qualitative or quantitative, more or less accurate knowledge). We used a fuzzy logic approach, which makes possible a more precise assessment than the DEXI one which only permits propositions having a value of truth or falsity. Decision trees aimed to predict taxa diversity according to management practices, sward composition, plant functional traits, and to some extent Ellenberg indices. The e-Flora-Sys website (<http://eflorasys.inpl-nancy.fr>) was used for mean functional traits and other plant species characteristics, such as whether they were known as a food resource for the different insect taxa. The effect of management practices (cutting vs. grazing, short vs. long rotation, high vs. low fertility) on habitat value of fauna was based on the literature and expert interviews. Decision tree outputs matched observed data (up to 571 grasslands in nine countries) reasonably well when data from numerous sites were available. Prediction of species richness appeared to be more accurate than that of abundance probably because abundance is more sensitive to various factors than species richness, especially to the climatic conditions of measurement years.

4d. Indicator-based evaluation tool for assessing the environmental roles of grassland at the regional level

An indicator system (MultiSward Indicator System - MIS) was defined to evaluate the impacts of ruminant stockbreeding systems on the quality of the environment and to assess a large range of ecosystem goods and services provided by grasslands and grassland-based systems at the regional level considering the four ecosystem services (provisioning, regulating, supporting and cultural services). MIS allows to compare 1) ruminant stockbreeding systems between them and with other farming systems within regions, 2) regions with different proportions of permanent and temporary

grasslands, forage maize and arable crops in their agricultural area, and 3) organic versus non-organic systems. The MIS is inspired by recent and effective systems, and particularly by the 28 agri-environmental indicators of the European Commission (EC) calculated at country level. Its structure is based on the DPSIR framework of the European Environment Agency. The MIS focuses on grassland-based and stockbreeding systems. Its scope is thus more restricted than the agri-environmental indicator system of the European Union but it tries to be compatible with this system. The MIS includes two lists, one calculated per farm type for a selection of regions and the second calculated per region for the same selection (all farm types merged), while the EC indicator list is calculated at country level (all regions and farm types merged). Because the availability of data varies for these different levels, the MultiSward and the EC indicator lists are not identical. They have their own specificities and are complementary. The lists adapted by MIS to farm types and to regions levels include respectively 23 and 45 indicators. The links between the MultiSward typology of ecosystem goods and services and the two sub-sets of MIS show that most ecosystem goods and services are taken into account by the indicators.

5. Identify and analyse the effects of socio-economic and policy scenarios on the future of grassland acreage (WP4, WP5)

5a. Relative competitiveness of grassland-based and non-grassland-based livestock systems

The competitive position of Irish dairy farms was compared against other EU-27 countries included in the FADN dataset. On a cash cost basis, the grass-based dairy systems compare favourably within in the EU but some margins of progress still exist. In particular, grassland-based systems of production had relatively low costs for seeds and plants, crop protection, purchased feedstuffs, depreciation and machinery. However, the competitive advantage displayed by Irish milk producers deteriorates when total economic costs are considered. The most significant imputed cost that contributed to the relatively high total economic costs experienced in grass-based systems of production in Ireland over the period is the charge for owned land. These relatively low costs were also counteracted, by high costs for fertiliser in the case of pure mono specific grass plots as it was the case in Ireland. Moreover, while grass-based systems can have low cash costs of production, they may also be characterised, by relatively low productivity in terms of labour, milk yields and constituents.

Structural differences in the different countries have differing implications for the efficiency of grass feed as measured by the constructed grass ratio (defined as the whole farm value of home-grown feeds for grazing livestock divided by the whole farm value of all feeds for grazing livestock weighted by the share of grassland area in the total forage area). The Irish and French farms show a positive relationship between cost efficiency and the grass ratio whereas they too have a negative relationship between technical efficiency and the grass ratio. German and Welsh farms exhibit a negative relationship between grass ratio and either measure of efficiency. This shows that where grass improves efficiency, it does so through its low cost and that grass forms an integral part of Irish cost competitiveness.

MultiSward also showed the possibility of substitution between forage area and cereal area influences farm profitability. In the areas where we can grow grass or corn silage, the competitiveness of grassland based systems using dual purpose breed vs. intensive dairy system with Holstein cows depends on the price ratio. With low price of milk and cereals, the profitability did not vary regardless of feeding system. With high price of cereals, the Holstein breed and maize system is more profitable and the higher the cereal price, the greater the benefit associated with intensification of the milk production system. This was largely due to the fact that less cows and heifers are required for the same milk production and that the additional land is then converted to cereal and rapeseed crops.

5b. Impact of policy changes and prices scenarios on the viability and persistence of sustainable grassland systems and the environment

In order to identify the main drivers that can support grassland-based systems or at the opposite threaten them, several price and policy scenarios were analysed with the FARMIS model in the case of 3 countries (Switzerland; Germany, Wales).

- A strong variation in input and output prices (50%) have a very significant effect on the grassland area, the intensity of management of grassland systems and the emissions towards the environment and are a key driver for the profitability of grassland systems. The high output price scenario results in an overall production increases (milk by +29% in Germany, +29% in Wales, +51% in Switzerland; beef output by +17% in Germany, +43% in Switzerland; and sheep by +13% in Wales) and more fodder is grown on arable land, temporary grassland increases while extensive grassland use is strongly decreasing (-42% in Germany - especially in the intensive dairy production regions of Schleswig-Holstein, Lower Saxony and Bavaria, -55% in Wales). This increases profitability in all farms types, but also leads to undesirable effects, such as further intensification and its related environmental problems. Increased input prices (fertilizers, energy, concentrates) in the baseline scenario led to a significant decrease in Farm Net Value Added in real terms according to countries and farm types. Dairy farms can maintain their income level, as farm and productivity growth and an increase in milk production can compensate rising input costs while, in contrast, beef farms see their income declines which raises serious questions with respect to their economic sustainability in the long term.

- The policy scenarios show that grassland abandonment can also be prevented without high output prices for products by area payments supporting grassland use especially when transmission of payments from arable land occur. However this may not work for all areas. Whilst this appeared to work successfully in Germany and Switzerland, in Wales and other grassland-dominated areas, the potential budget transfer from arable areas is low and therefore capacity for increased grassland payments is reduced.

In conclusion, it can be seen that input and output prices have a significant effect on the area and intensity of grassland systems. Use of support payments to encourage less intensive grassland farming appears to achieve its goal when CAP budget is transferred from arable areas but may be more problematic when this budget is transferred from existing more intensive grasslands. So, specific supports to grasslands can be effective in maintaining grassland acreage.

6. Exchange of information and dissemination of MultiSward achievements and knowledge to the socio-economic stakeholders and the scientific community (WP6)

6a. dissemination through conferences and interaction with key groups of stakeholders

MultiSward topics and results have been widely spread during the whole project at national and international scales and to various communities. In particular, MultiSward played a major role in organizing the annual General Meetings of the European Grassland Federation (EGF) which is the European wide forum for research workers, advisors, teachers, farmers and policy makers with active interest in all aspects of grasslands in Europe. During the whole project, several meetings of the national grassland societies were organised where the MultiSward project and results were presented and promoted in maternal language of the communities.

Beyond conferences, one of the major objectives of MultiSward was to facilitate interaction with the stakeholders, through dedicated meetings and adapted tools such as questionnaires, to contribute to the dissemination of the results, but also to better identify the expectations of the stakeholders regarding the various ecosystemic services likely to be provided by grasslands. Among the most significant meeting we should pointed out (i) a first meeting held right after the beginning of MultiSward (EGF in Kiel in 2010) and gathering more than 40 attendants covering a broad range of countries and of stakeholders was mainly devoted to the identification of the main expectations, and (ii) at the end of the project, a dedicated event was organised in Brussels with members of the European Commission (mainly DG Agri, DG Research and representatives of various European countries) to present the achievements of the project and to discuss the levers that could be implemented to better use the grasslands and as a consequence to improve both the economic performance of the animal farms and the environmental benefits. The feedback from the participants was very positive and showed that the MultiSward project was targeting the right stakes and that the results met the expectations of the various groups of stakeholders.

6b. Web-site combining with an e-learning centre and handbook on grassland

MultiSward had the objective to create an e-learning centre dedicated to grasslands. The e-learning centre was progressively developed throughout the whole project and is available in 4 languages in websites that are mirrors of each other. The structure, based upon a Wiki system, makes it possible to regularly upgrade it with contributions from specialists of grasslands and forage crops. The four versions were sent to national grassland societies (France, Germany, Poland, and UK). The material is available for free if other countries which want to translate it in their own language. The URL address used for the development of the site still gathers the four languages and may be searched: http://appli.poitou-charentes.inra.fr/internet/e-learning/multisward_eng/doku.php

A handbook published in March 2014 is dedicated to the state-of-the-art of grasslands and forage crops in Europe "Grasslands and herbivore production in Europe and effects of common policies". It puts together the deliverables from a wide range of MultiSward tasks, and includes material from the e-learning centre. The handbook provides a highly documented description of grassland and herbivore production in Europe. A special section is devoted to the environmental benefits provided by grasslands and how the management may influence these environmental services. A series of case studies covering the whole European diversity allow documenting the relationship between grasslands and environmental services.

7. General conclusion and future prospects

The MultiSward project aimed to conceive, evaluate and promote sustainable ruminant production systems based on the use of grasslands with a high level of multifunctionality in order to optimize the provision of environmental goods and biodiversity preservation, but also economic efficiency and provision of quality food. From a scientific point of view, most of the initial objectives were reached: (i) production of a state-of-the-art review about the roles and utility of grassland and stakeholders expectations; (ii) assessment and optimization of the simultaneous production of various services by MSS; (iii) design and evaluation of innovations in system management; (iv) provision of adequate tools to assess the performances of the systems at different scales and (v) identification and analysis of the effects of socio-economic and policy scenarios on the future of grassland / farm performance.

Despite these significant progresses, some key research questions remains to be solved:

- Developing management and breeding approaches to ensure consistent legume yield would address a key issue that inhibits the uptake of MSS by farmers – their perceived unreliability in terms of yield and species composition. The issue of decreasing sward legume content was particularly evident in the case of red clover in the project.
- Climate change will result in more extreme climatic conditions with longer periods of extreme ambient temperatures and more variation in climate during and within the season thus requiring adaptation of forage production (including

genetics). Development and test of new plant production systems and new multispecies grassland having fewer requirements for water and higher resilience to dryness is required.

- The most profitable genotype or breed is a key factor to return the highest profit per unit of the most limiting input and to limit harmful environmental emission. This means to select animals with a better equilibrium between production and robustness for intensive systems and to exploit the adaptive capacity of herbivores to make better use of grassland in marginal area (land on which the only thing that will grow is grass). This would mean a better understanding of adaptive capacity (genetics, early life experience, ability to cope with environmental fluctuations).

- MultiSward focused on nitrogen but phosphorus is a limited resource that can be a threat to the environment. It would thus be important to also improve our understanding about phosphorus cycle for developing phosphorus efficient grasslands.

- We still need to develop novel grazing systems that are technically and socially feasible and economically viable for large, medium and small scale farming systems (including part-time farming) everywhere in Europe.

- The delivered version of the tools mainly reflects the state-of-the-art, and the limitations of the current knowledge. The evaluation tools can be used for global evaluations of different scenarios. However, we believe that future programs are necessary to improve their precision and robustness. Particular attention will be given to gradients of situations in term of acreage of grassland within territories and intensity of use.

Apart from research, a key issue is to convince farmers to continue to use grasslands in particular, but not exclusively, in those areas where the cultivation of arable plants such as maize is an attractive alternative and help them to progress technically and economically. Here it would be particularly interesting to build a European grassland network aiming at synthesising, sharing and presenting innovations resulting from MultiSward (and others projects) in order to develop sustainable and efficient management systems of grassland. Such a network can be based on a so-called multi-stakeholder approaches involving farmers and farmers' groups, SMEs, diverse scientific disciplines, research institutes, cooperatives, Livestock Breeding Association, NGOs promoting product qualities such as labels and other stakeholder groups or experts in the field of grassland use and grassland protection. The active involvement of representatives of the industry with their local knowledge and expertise is central to the network approach.

Potential Impact:

MultiSward brings, for the first time, a detailed EU wide and multifunctional oriented overview of grassland-based ruminant production systems thus opening the opportunity to define on a new basis the contribution of ruminant production on grassland to biodiversity conservation and the provision of ecosystem services. It thus provides sound data for recognition of the strengths of these systems.

1. European level added value of the project

MultiSward brings together a wide group of cross disciplinary expertise in agriculture: agronomy, plant genetics, grassland science, animal husbandry and nutrition, ecology, environmental science, indicators design and evaluation, economy, sociology, data mining and modelling. Strong connections between teams that never worked together before for most of them have been created. In particular strong connections were established between animal and vegetal teams. MultiSward partners have provided large resources gathered together (numerous experimental sites, both for plant and animal based experiments, several case studies with on-farm surveys, exchange of data) from several countries ensuring a representative coverage of the main agro-ecological contexts and farming systems in Europe from Atlantic, Nordic, Continental Europe, humid mountains and Mediterranean zones. The teams are today ready to develop new collaborations (including also with new teams) for other projects to produce innovation in aspects not tackled by MultiSward and by developing a European grassland network involving farmers and farmers' groups, SMEs and others actors for the development of multifunctional and more resource efficient grassland-based production systems at a large scale.

The active participation of stakeholders from international, national and regional levels throughout the project was a key objective and has allowed assessing their requirements, sharing experiences, learning together, contributing to decisions, and determining further needs for grassland systems in Europe; and has finally ensured that relevant information on grassland multi-functionality and the sustainability of grassland-based systems was delivered to end users.

2. Provision of information for securing optimal European grassland acreages

MultiSward contributes to the maintenance of total grassland acreage by the provision of scientifically based information and expertise that are of the utmost practical relevance for farmers and for EU agricultural policy for maintaining grassland acreage.

2a. State of grassland acreage in Europe and stakeholders expectations with respects to the service expected for grasslands

MultiSward has provided a detailed view of grassland acreage and utilisation in Europe to policy makers and education. All available information on grassland is published in a handbook (available also as free access .pdf file) which provides a highly documented description of the different types of grasslands, herbivore production, farming structure from national and international statistical resources and information, environmental benefits provided by grasslands and highlight the socio-economic and political driving forces that have contributed to the decrease of grassland acreage

during the last decades. This work demonstrated that statistics on grassland acreage significantly differ between Eurostat, FAOSTAT and national databases and even within databases over time (at least for some countries) Sometimes important information is lacking or not clearly collected. This clearly obscures the vision of policy makers on grassland and does not allow taking into account all the diversity of grasslands by the Common Agricultural Policy (CAP). A better definition and classification of grassland terms should help to optimize the supports for grassland and to secure grassland acreage in Europe while maximising environmental benefits with well-targeted premium. MultiSward participated to a group of experts for drafting a document on 'Grassland Term Definition and Classification' in collaboration with the Alterra project financed by ESTAT. The proposal is a trade-off between the practical aspects related to data collection and the level of precision that is necessary to reach the objectives described above. A leaflet summarizing the basis for new definitions was disseminated to the DGs participating at the final MultiSward meeting in Brussels, which can represent the basis for new and efficient policies for supporting grassland acreage.

The work with stakeholders (either in real life meetings or virtual using the web) provided insight in their view about the different ecosystem services that grasslands provide and of different components of these services for different groups of stakeholders in different regions. Data confirm that the different services provided by grasslands are well recognized by all relevant stakeholder groups. This is an encouraging and important result showing that it is crucial for a majority of stakeholders that future policies continue to support conservation of grasslands.

2b. Evaluation of impacts of policy changes and prices scenarios on the viability and persistence of grassland systems.

MultiSward demonstrated the competitiveness of grassland based production systems. Simulations using FADN dataset have showed, on a cash cost basis, that grass-based dairy system (like in Ireland) compares favourably within the EU even if some margins of progress still exist. Grassland-based systems have relatively low costs for seeds and plants, crop protection, purchased feedstuffs, depreciation and machinery. Results demonstrate that where grass improves efficiency, it does so through its low cost. However, these relatively low costs can be counteracted by high costs for fertiliser in the case of pure mono specific grass plots as it was the case in Ireland and structural differences in the different countries have also differing implications for the efficiency of grass feed. Beyond the possible premium, these results should help to convince farmers about the competitiveness of grassland based systems, their economic strengths and productivity.

MultiSward has identified some external drivers that can support grassland-based systems or at the opposite threaten them. Clearly, we have shown that specific supports payments for encouraging less intensive grassland farming can be effective in maintaining grassland acreage but their effectiveness will depend on the scenarios of prices evolution and the range of the effect can vary according to the country. However, use of support payments to encourage less intensive grassland farming appears to achieve its goal when CAP budget is transferred from arable areas but may be more problematic when this budget is transferred from existing more intensive grasslands and high output price increases profitability in all farms types, but also leads to a further intensification and its related environmental problems and a decrease in grassland area. These results provide useful information to design new policies in favour of grasslands.

3. Enhancing the competitiveness and environmental benefits of grassland based production systems

Research conducted under the MultiSward project provides ways to improve the productive performance of grassland based systems and overall returns for the farmers while enhancing the environmental performances using multispecies sward. While the agronomic benefits of grass-legume mixtures over grass monocultures have been recognized for a long time, and extensively implemented into productive agriculture in a few regions (e.g. Switzerland), the simplicity of managing grass monocultures and the low price of nitrogen (N) fertilizer have in the past inhibited the use of multispecies mixtures (MSS) for forage production in many European countries.

3a. Reinforcing competitiveness of grassland based ruminant production systems

Multispecies sward based on four different species belonging to four different functional groups (non-N fixing vs. N-fixing and shallow rooting vs. deep rooting) performs very well. Biomass production results clearly showed that there was no detriment to DM yield in legume-based MSS compared to PRG monocultures receiving high inputs of external nitrogen fertilizer. Indeed, in some instances MSS were more productive than the latter. Increased use of MSS therefore potentially represents a substantial economic and environmental saving when the various costs associated with the use of nitrogen fertilizer are considered. In addition, results showed that animal intake in sheep, beef cattle and dairy cows were positively related to mixture complexity. Increased herbage intake in dairy cows translated into higher milk yields per cow, and, ultimately, into higher milk output per hectare. This is an important result for the dairy sector, showing clearly that MSS can contribute to more sustainable ruminant production systems.

Besides forage production, MultiSward also demonstrated some progress from grassland management. Extending the grazing season reduces the requirement for silage, purchased feedstuffs, housing, and slurry storage and spreading, thereby improving the economic returns to the producer from their ruminant production system. While weather conditions can impact grazing efficiency, management techniques such as on/off grazing, examined in this project will allow the farmer to produce milk or meat from grazed grassland, but will minimise the impact of the animal presence in the sward on future herbage production, soil properties and N loss. In particular nitrate leaching is not (or hardly) affected by autumn grazing. Economical returns of grassland based systems are also greatly affected by animal

breeds; some being better suited to grassland based low input ruminant production systems. This was clearly demonstrated for the Holstein-Friesian breed which is less efficient in grassland based systems than more robust breed (Normand, Norwegian) and crossing breed such as Jersey or Norwegian Red with Holstein-Friesian resulting in hybrid vigour. This was also the case for sheep; local breeds are more efficient at converting grassland to live weight in Poland than imported breeds. This is an important conclusion that clearly demonstrates that farmers should adapt the genetic of their herd to the desired system to maximise benefits (the right animal for the right system). The animal required for efficient grassland-based production systems (low inputs systems or organic systems) must be robust and 'easy care' and capable of high level performance in grazed pasture.

3b. Enhancing the environmental benefits of grasslands

MultiSward has contributed to optimise the major environmental roles of grassland through the concerted use of plant species diversity and adapted management practices at the farm level and by the integration of low productive semi-natural grasslands into efficient systems at the landscape level. The results showed that the use of legume-based multi-species swards can reduce emission (per unit of forage produced) impacting air quality and water quality while grassland plant diversity can be considered as positive for the conservation of faunistic diversity as a whole. Promoting heterogeneity thank to a differentiated grassland management at the farm scale is an important component of diversity conservation in ruminant production systems located in grassland dominated landscapes. Such a strategy should mainly consider supporting unfrequently mown grasslands receiving no or little nutrients and situated in less favourable locations, as well as extensively grazed grasslands. Developing appropriate grazing management strategies can increase grassland biodiversity. For example introducing an Ecological Rotation, a strategy examined in the WP3, can increase the quantity of flowering plants in semi-natural upland grassland areas in France and thereby increase the abundance of bumblebees and butterflies.

4. Development of scientifically-based tools to promote positive externalities and best use of grasslands

Indicator-based evaluation tools sensitive to the diversity of the grasslands and able to evaluate a wide array of impacts were developed for the local and for the regional scale. They have the potential to improve the evaluation of production systems using either a diversity of grassland types, a diversity of species in their swards or both, as compared to already existing evaluation systems. At both scale, the evaluation tools were developed to be readily usable.

At the local scale, the indicators were developed in order to be calculated based on simple and easily accessible variables describing management and sward composition obtained from simple interviews with farmers and botanical surveys. Moreover, the implementation of the calculation in a free website (<http://e.florasys.inpl-nancy.fr>) is in progress. In its present form, the evaluation tool makes it possible to sort different scenarios of grassland-based ruminant systems in terms of their impact on biodiversity. But future programs including global surveys of management and biodiversity of permanent grasslands are necessary to improve the precision of the current evaluation tool.

At regional level, the objective MultiSward Indicator System (MIS) was to focus on grassland and livestock systems in order to evaluate the impacts of ruminant systems on the quality and the use of natural resources and to assess a large range of ecosystem goods and services provided by grasslands and grassland-based systems. The scope of MIS is thus more restricted than the agri-environmental indicator system of the European Union but it tries to be compatible with this system. The MIS is based on data that are available within EC institutions to ensure that other actors could use it in the future and that it could be adopted in the medium term in other studies and possibly become a reference system for EUROSTAT and other EC agencies. The indicator set should thus be valid in the future in all European Union regions and was quantified during the project in a limited number of regions that are representative of the diversity of stockbreeding systems and in most bio-geographical and farming system regions of Europe.

The evaluation of externalities of livestock systems are more difficult to quantify than the production of milk or meat. MultiSward has developed tools using simple and easily accessible variables describing management and sward composition, which makes easier the holistic evaluation of the systems and should help (i) farmers (and rural extension services) to enter into virtuous circles of progress by monitoring the overall performances of the systems and taking the right decisions, and (ii) policy-makers to be equipped with set of indicators to assess the effectiveness of incentives and to design new and more efficient policies.

5. Contribution to the actual European policies and regulation

MultiSward has contributed to the strengthening of several European policies and action plans by producing scientific data through direct measurement, through the evaluation of sets of indicators and by modelling:

- The Nitrate Directive (Directive 91/676/EEC) and the Water Framework Directive (river basin management plan) which aims at improving water quality by demonstrating the role of MSS to reduce the risk of nitrate losses compared to highly fertilized grass and by showing the lack of effect of extending the grazing season on nitrate leaching. These results will reinforce the positive role of grassland in the context of nitrate directive and contribute to maintain or even increase the acreage of grassland especially in areas of structural N surpluses;
- The EC Biodiversity Strategy (ECBS) which aims at preventing biodiversity loss and attacking the causes of biodiversity loss in Europe. MultiSward has identified ways of progress in the management of permanent grassland to

increase flora and fauna biodiversity. The provision and utilisation of valuable sets of indicators can be used by NGO's to demonstrate the contribution of grasslands to the conservation of farmland biodiversity in different biogeographical European regions, by policy-makers to monitor the effectiveness of incentives, and by farmers to maintain biodiversity at farm scale;

- The Global Plan of Action for the Conservation and Sustainable use of Plant Genetic resource for Food and Agriculture by demonstrating the efficiency of using species mixtures. In particular, results from the genetic change experiments identified a number of loci in red clover for which significant changes in allele frequency had occurred over time. These loci represent candidates for genetic factors involved in persistence which is an important breeding goal for the future;
- The Agriculture and Climate Change (mitigation and adaptation) policy. MultiSward provided evidence that GHG emission can be modulated by farming practices and some rooms to manoeuvre were given;
- The "Health Check" of the CAP (e.g. phasing out milk quotas, cross compliance, shifting money from direct aid to Rural Development) by analysing the effectiveness of present agricultural and agri-environmental policies on grassland acreage protection and by the analysis of scenarios and their impacts on the sustainability of grassland-based systems and total grassland acreage (modelling). In the long-term, this will support the enhancement of the contribution of the CAP to sustainable and multifunctional farming systems.

6. Dissemination activities to strengthen the impacts of MultiSward on European livestock production system and European citizen

MultiSward disseminated knowledge in peer-reviewed scientific journals and in addition, achievements and knowledge were disseminated to the socio-economic stakeholders, especially policy-makers, farmers, rural extension services, organisations involved in or concerned with environmental services. Next to the top-down dissemination which is commonly implemented in research projects, MultiSward has adopted a knowledge interaction approach through a participatory framework to improve the exchange of information and experience with the various stakeholders, ensuring a maximum impact of the project and to advertise the positive impacts of grassland-based production systems to the EU citizens.

MultiSward disseminated information through a number of peer-reviewed papers (much of the experimentation carried out was long-term in nature, which means that final results were obtained just as the MultiSward project ended and that the production of papers will continue after the end of the project), and through active participation to international congresses, mainly to the annual meetings of the European Grassland Federation (EGF) which is a forum for research workers, advisors, teachers, farmers and policy makers with active interest in all aspects of grasslands in Europe. To maximise the impact of this dissemination, two special sessions of the last EGF meeting (2014) were dedicated to MultiSward with several invited papers and oral presentations.

To maximise the impacts of MultiSward to European livestock sector, several meetings were organized (i) with the national grassland societies (especially France, Germany, Ireland, Italy, UK, the Netherlands, Poland) where the results and achievement of MultiSward were presented and promoted to the public in mother tongue, and more presentations will be done in these societies after the end of the project ; (ii) a dedicated event was organised in Brussels (February 2014), with members of the commission, mainly DG Agri, DG Research and representatives of various European countries to present the achievement of MultiSward and to discuss with policy-makers of the levers identified by MultiSward project that could be implemented to better use the grasslands in Europe in the future. Finally MultiSward facilitated interaction with the stakeholders, through dedicated meetings and adapted tools (such as questionnaires, web-site) to contribute to the dissemination of the results, and to better identify the expectations of the stakeholders. MultiSward hypothesized that their implication in the project will facilitate the appropriations of the results and concepts produced.

In addition, the e-learning centre was translated in 4 languages (English, French, German, and Polish) and the four versions were sent to national grassland societies. These national societies will be in charge of the product and its evolutions. This will help farmers and extension services to get more confidence on grazing and grassland based systems by improving their knowledge in a dynamic and up-to-date way.

The results of MultiSward can be commercially exploited by farmers putting into practise some innovations as for example the use of multispecies sward or extending the grazing season. Results could further be commercially exploited through their contribution to forage plant breeding. Notably, results from the genetic change experiments identified a number of loci in red clover for which significant changes in allele frequency had occurred over time. These loci represent candidates for genetic factors involved in persistence, an important breeding goal. Thus, molecular techniques could be applied to red clover germplasm in order to select appropriate genotypes for crossing programmes aimed at enhancing persistence under grazing in agronomically-acceptable populations.

Some dissemination of results to wide audience was carried out. An example is an information booklet for UK farmers produced by HCC (Meat Promotion Wales), which was recently updated (March 2014) with information gained from the comparisons of MSS and highly fertilized swards.

7. Conclusion

MultiSward has provided scientifically based information and expertise that are of the utmost practical relevance for

farmers and for EU agricultural policy for maintaining grassland acreage and developing competitive, productive and environmentally friendly livestock systems. :

- MultiSward has pointed out the need for improving European statistics on grassland acreage and grassland term definition to design more efficient public policies for maintaining grassland acreage. Useful information was also provided to design new policies in favour of grassland. In the long-term, MultiSward outputs will support the enhancement of the contribution of the CAP to sustainable and multifunctional farming systems.
- The results concerning the competitiveness of grassland based system should help to convince farmers of the economic strengths and productivity of grassland that will also help to maintain grassland acreage in the future.
- Margins of progress were demonstrated in grassland based production systems, showing clearly that multispecies swards can contribute to more sustainable ruminant production systems; that performance of grassland based system requires well suited breed; and that developing appropriate grazing management strategies can increase grassland biodiversity in extensive systems. These are very important results for both farmers and the society.
- MultiSward has developed tools using simple and easily accessible variables describing management and sward composition, which should help (i) farmers to enter into virtuous circles of progress to develop more sustainable systems, (ii) policy-makers to assess the effectiveness of incentives and to design new and more efficient policies, and (iii) NGOs and other stakeholders to better evaluate the contribution of grassland to environment in various conditions.

List of Websites:

www.multisward.eu

Related information

Result In Brief	Greener pastures for Europe's farms
Documents and Publications	final1-logo-and-contact-details-multisward.pdf

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