MultiSward

Multi-species swards and multi scale strategies for multifunctional grassland-base ruminant production systems

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The characteristics of sustainable grass-based ruminant production systems are identified and the key measurements of sustainability to be undertaken in Task 4.2, Task 4.3 and Task 4.4 are established

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Workpackage concerned: 4

Concerned workpackage leader: Pat Dillon

Dissemination level: PU
Managing European Grasslands to Increase the Sustainability and Competitiveness of Livestock Production Systems

Introduction
Agriculture plays a small part in the economics of the European Union (EU) member countries, contributing about 2% of the gross domestic product (GDP), with 4.7% of the EU population employed in the primary agricultural sector. However, in terms of its impact on the environment and natural resources, the contribution of agriculture is much more significant, accounting for 45% of EU total land use and 30% of total EU water use (Parris, 2001). As well as producing food and fibre, agriculture is also increasingly being required to provide various environmental services, such as habitats for wildlife, providing ecological services, for example, acting as a sink for greenhouse gases (GHG), and supplying amenities, such as attractive landscapes and areas for outdoor activities. Grassland area in Europe experienced a substantial reduction during the 20th century. In the period 1975 to 1995 there was a 12% reduction in the area of permanent pasture in 9 countries of the EU. In France alone there was a reduction of 2.4 million hectares of grassland during this period. The greatest reduction was in lowland areas of high fertile soils, while permanent grasslands were maintained in harsh natural conditions such as mountain, karst and wet soils. In lowland areas ploughing, in combination with abundant organic and chemical fertilizer application, contributed to water and soil pollution (Tamminga, 1996) and loss of biodiversity (Atkinson and Watson, 1996). In harsh environments agriculture abandonment has resulted in the encroachment of shrubs and trees contributing to increased risks of fires and loss of landscape amenity and biodiversity (MacDonald et al., 2000; Moreira et al., 2001).

In recent years Europe’s agric-food industries are being rapidly re-shaped by international and internal policy changes, combined with a diverse range of growing public concerns, including climate change, environmental sustainability, food safety and security, animal health and welfare, and ethical foods and free trade. Formidable challenges and uncertainties point to the need to develop a new model for agriculture and food production. This model must meet criteria such as profitability at farm level, produce marketable ‘value-added’ food products, environmental sustainable, capacity to cope with climate change and be energy efficient. The concept of sustainable-competitive agriculture meets multifunctional objectives and provides important advantages for dairy and meat products produced from grass-based systems. When agricultural sustainability is considered and research in the area undertaken it often focuses on the environmental aspects and impacts of production systems without considering the long-term economic and social sustainability of individual farms or agricultural catchments.

In this review paper we are proposing that grassland has the potential to increase the sustainable-competitiveness of ruminant agricultural production in the EU. Three key aspects of the sustainability of grassland-based ruminant production will be considered which include economic, social and ecological. Economic sustainability will include production costs, competitiveness, and product quality and energy use efficiency of grassland systems. Social sustainability relates to both internal, which includes the working conditions for the farm owner and employees, and external, which relates to the influence of the farming system on the well being of people and animals. Ecological sustainability concerns benefits of grassland on soil, water,
climate, flora and fauna. Within each key aspect grassland has the potential to increase overall sustainability at farm level, catchment/regional and globally.

**European grasslands**

Grassland and forage crops on arable land account for a large proportion of the utilized agriculture area (UAA) of the EU. In 2007, about 33% of the total UAA in the EU-27 was in use as permanent grasslands, and 11% of the UAA were cultivated with forage crops such as temporary grassland and green maize. Countries like Ireland (76%), United Kingdom (62%), Slovenia (59%) and Austria (54%) have the greatest proportion in permanent grassland; while counties like Denmark (8%), Bulgaria (9%), and Germany (29%) have a low proportion in permanent grassland (Eurostat, 2010). Between 1975 and 2001, permanent grassland decreased by about 17% in the EU-15; this is a rate of -0.7% per year (Gobin et al., 2006). Grassland serves as a forage area for cattle, sheep and goats with beef and veal, sheep and goat meat amounting to 11% and milk to 14% of total EU-27 agricultural production value. Beyond its contribution to meat and milk production, permanent grassland provides a number of environmental and social benefits. Compared to arable land, grassland is associated with a better conservation of soil against erosion, reduced runoff and leaching of nutrients into surface and ground water, and contributes to flood control (Briemle and Elsasser, 1997). Cerdan et al. (2010) estimate soil erosion rates in a European context to be much lower on grassland (c. 0.30 t/ha/year) compared to that from arable lands (c. 3.6 t/ha/year). The presence of vegetation on grassland, combined with reduced soil erosion, reduces nutrient and soil run off. Grasslands can be considered as biological filters and as a result prevent chemicals such as N, phosphorous (P) and pesticides entering surface and ground waters (Jankowska-Huflejt, 2006). As a result of their filtering ability grasslands have an important role to play in ensuring the limit of 50 mg N/L in surface and ground water is complied with as directed in the Nitrates Directive. In the debate on climate change caused by anthropogenic GHG emissions, grassland is classified as an important carbon (C) sink, due to its high organic matter content relative to arable land (IPPC, 2000). Further, grassland constitutes a characteristic element of European culture landscape, and the maintenance of semi-natural grassland habitats through traditional agricultural use is vital for the protection of biodiversity (Zdanowicz et al., 2005). Within the Natura 2000 Network, established according to the Birds and Habitats Directives, grassland constitutes the dominant type of agriculture land use. More than 18% of EU total grassland is located within designated Natura 2000 sites (Cooper et al., 2009).

There were approximately 78 million grazing livestock in the EU-27 in 2007 (Table 1). More than 80% of grazing livestock units in the EU-27 are cattle, with dairy cows accounting for 31% and ‘other cows’ (mainly suckler cows) for another 16%, although this varies widely between countries (Table 1). Sheep and goats represent another 14% of grazing animals in the EU-27 (Table 1). Dairy cows account for 50% or more of the grazing livestock in The Netherlands, Lithuania, Latvia, Poland and Estonia, while suckling cows comprise 20% or more of the grazing livestock in Portugal, Belgium, France, Spain, Luxemburg and Ireland. The number of dairy cows and suckling cows is relatively balanced in Belgium, Greece, France, Luxemburg, Ireland, Portugal and the United Kingdom. In Spain, Greece, Cyprus, Portugal, Bulgaria and the United Kingdom sheep and goats represent 20% or more of the grazing livestock. Between 2003 and 2007 on average each year about 6% of dairy farmers ceased milk production, while farmers keeping ‘other cows’ were much more
stable although having markedly smaller herd size. In the EU-15, specialised dairy farmers keep almost 80% of all dairy cows, but utilise less than 20% of the total permanent grassland area. The relatively low proportion of grassland in specialised dairy farms is explained through the higher stocking rate on these farms and the higher proportions of green maize and temporary grassland used as forage crops.

Table 1 Numbers of dairy cows, other cows and sheep in the EU-27 countries, Norway and Switzerland in 2007.

<table>
<thead>
<tr>
<th></th>
<th>Dairy cows ('000)</th>
<th>Other cows ('000)</th>
<th>Sheep ('000)</th>
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</thead>
<tbody>
<tr>
<td>Austria</td>
<td>522</td>
<td>268</td>
<td>328</td>
</tr>
<tr>
<td>Belgium</td>
<td>524</td>
<td>545</td>
<td>151</td>
</tr>
<tr>
<td>Bulgaria</td>
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<tr>
<td>Cyprus</td>
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<td>3</td>
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</tr>
<tr>
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<td>417</td>
<td>154</td>
<td>173</td>
</tr>
<tr>
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<td>545</td>
<td>106</td>
<td>157</td>
</tr>
<tr>
<td>Estonia</td>
<td>108</td>
<td>9</td>
<td>83</td>
</tr>
<tr>
<td>Finland</td>
<td>296</td>
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<tr>
<td>France</td>
<td>3,815</td>
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<tr>
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<td>40</td>
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<tr>
<td>Germany</td>
<td>4,076</td>
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</tr>
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Source: MULTISWARD Deliverable D5.1 Socio-economic and political driving forces.

Policy changes

Farm structure, production activities and agriculture land use are subject to market and policy influences, of which the Common Agricultural Policy (CAP) plays a central role. Many CAP instruments are important for ruminant production systems including direct payments, the Good Agricultural and Environmental Conditions (cross compliance), milk quotas, investment aid, Agri-Environmental Measures, Less Favoured Areas and diversification supports. However, some of these measures have not been very favourable to maintaining grass based production systems. For example, before the 2003 CAP Reform a higher proportion of the CAP Budget (especially in
Pillar 1) was spent per hectare of arable land compared to grass land and in field crop specialist holdings compared to grazing livestock specialist holdings. While the differences were partly compensated for by Pillar 2 expenditures post the 2003 CAP Reform, imbalance still remains. CAP has established rules for the maintenance of permanent grassland through eligibility rules and minimum requirements as preconditions for receipt of direct payments. Currently the proportion of permanent grassland must not decrease by more than 10% relative to a ‘reference year’. The requirement for the protection of permanent grassland can be considered recognition of the positive impacts of grassland compared to cropping/arable land on a range of ecosystems services.

The EU CAP was set up in 1957 with the aim of guaranteeing food security in post war Europe at stable and reasonable prices to producers by maximising production and protecting domestic agriculture from foreign competitors (Whetstone, 1999). By the 1980’s the EU had to contend with almost permanent surpluses of major farm commodities. This required the introduction of production limits, e.g. in the form of quotas in the case of milk production. While the adoption of milk quotas ensured price protection for EU producers, the scheme required the use of export refunds for milk products onto world markets and subsidies for various forms of disposal (ice cream making, confectionary, and animal feeds) within the internal EU market. The MacSharry reforms to the CAP, agreed in 1992, instigated a reduction in market support prices and instead provided direct compensation for farmers by means of direct aids. Several rural development measures were introduced, notably to encourage more environmentally friendly and less intensive systems of farming. This shift in emphasis in the CAP entered a new phase in 1999 with the ‘Agenda 2000’ reforms. These reforms further reduced price supports and compensated farmers with direct payments aimed at enticing more environmentally sensitive farm practice.

In June 2003, a further fundamental reform was agreed following an undertaking to carry out a Mid-Term Review of Agenda 2000. This reform, known as the Luxembourg Agreement or Medium Term Review of CAP, constituted a fundamental change in the way the EU supports farming. The aim of the Luxembourg Agreement was to take the concerns of the consumers and taxpayers into account while giving EU farmers the freedom to produce what the market demands and to continue to protect farmers’ incomes through a mechanism that does not distort international trade. The Luxembourg Agreement severed CAP income support from agricultural production. It introduced an area-based ‘single farm payment’ (SFP) for EU farmers, decoupled from production, and cross compliance (CC). This linked direct payments to compliance with environmental, food safety, animal and plant health and welfare standards as well as the requirement to keep all farmland in ‘good agricultural and environmental condition’.

At present the CAP is divided into two main ‘pillars’, which differ in terms of financing, functioning and structure. Pillar 1 (financed fully from the EU budget) consists of direct payments (income support) to farmers and market intervention such as subsidies. Pillar 2 – the rural development policy - is partially co-funded by member states and regional administration. This rural policy aims to improve agricultural and forestry sector competitiveness, protect the environment and countryside, enhance quality of life in rural areas and diversify the rural economy. In the EU-15 member states Pillar 1 consumes over 85% of total CAP expenditure. The
widespread use of a historic basis for allocating payments under the current Single Farm Payment Scheme has largely fossilised the pre-existing funding pattern, generally favouring intensive agriculture. In the EU-12 countries, the Pillar 1 budget is far less dominant (less than 60% of total CAP expenditure) and distributed more evenly across different types of farmland, using a flat area payment. Therefore in the EU-12 countries a much greater proportion of CAP expenditure is targeted at semi-natural grassland and high nature valued farmland. Considering the relevance of direct payments and Pillar 2 support for dairy, beef and sheep farms, especially those with lower intensity levels, future CAP budget and support measures are key factors determining the future of grassland use.

**Contribution of Grassland to Sustainability**

Grassland has a range of associated values, beyond use as a source of income from livestock production. They can provide environmental benefits in terms of their capacity to help in flood control, contribute in providing a sink for C, support biodiversity, both natural plants and animal resources, and offer landscape which can embody a range of cultural, heritage, aesthetic and other values important to society.

1. **Flood control**

   Appropriately managed agricultural land can retain a large quantity of water. This stabilises water flow from agricultural land and mitigates flood damage downstream off farm areas. A large quantity of rainfall within a short period may result in flooding in downstream areas. Water can be retained by grassland for long periods depending on natural and artificial features (e.g. ponds, dykes, etc.), land use pattern and farm management practices. The importance of these functions differs across countries because of variation in the potential risk level of adverse weather conditions. Permanent grassland has greater water infiltration rates than arable land (Briggs and Courtney, 1989). Compaction from grazing can reduce infiltration rates to as low as zero on severely compacted areas; light to moderate grazing may reduce infiltration rates by up to 25% (Gifford and Hawkins, 1978). Grassland, both drained and undrained, results in lower overland flow of rainwater and less soil loss from silty clay soils than does arable land (Chisi and Zanchii, 1981). Grassland has more or less continuous cover which intercepts rainfall and restricts overland flow. Higher soil organic matter accumulation, improved rooting and high earthworm activity in grassland soils compared to arable soils increase water infiltration rates.

2. **Water quality**

   Many authors have reported that grassland has a better effect on water quality and water resources than do other crops (Briggs and Courtney, 1989; Benoit et al., 1995; Benoit and Simon, 2004). Permanent grasslands are recommended in areas with soil types from which there is a high risk of nitrate leaching (Bossuet et al., 2006). Permanent grassland acts as a store for N, as indicated by its high organic matter content (Brogan, 1966; McGrath and Zhang, 2003; O’Connell et al., 2003), lowering the risk of N loss to water. In long-term productive grassland soils there is normally a positive balance of gross N mineralization against N immobilisation, indicated by net N mineralization (Jarvis and Oenema, 2000). Sward structure (multi-species), presence of shrubs and trees all effect soil structure and percolation and therefore the filtering capabilities of soils. Wetland areas act as filters, thereby reducing the amounts of sediment and nutrients entering rivers, lakes, streams, etc. Farmland vegetation can affect rate of surface run-off from slopes into rivers and streams and
can further affect water quality in terms of transport of nutrients, sediment and microorganisms to surface waters (Hopkins and Holz, 2006).

Across Europe, nitrate levels in respect of cut grassland are lower than from other crops (Benoit and Simon, 2004); particularly when N fertiliser is applied in accordance with crop yield, up to 400 kg N/ha/year. Time of N application to grassland can have an effect on water quality; nitrate levels tend to be higher with autumn applied N fertiliser compared to spring and summer applications. Nitrate leaching is usually higher from grazed grassland, but at moderate N application rates (c. 200 kg N/ha/year) nitrate leaching is moderate. At fertiliser N rates greater than 300 kg N/ha/year nitrate leaching can be variable and high (Benoit and Simon, 2004), ranging from 5 to 200 kg N/ha/year (Ledgard et al., 2009). Nitrate leaching increases exponentially with increased N input from fertilisers and/or N2 fixation by clover (Ledgard et al., 2009). Incorporating white clover into perennial ryegrass swards may reduce the requirement for N fertiliser application, but studies have shown that nitrate leaching from grass clover swards is similar to (Cuttle et al., 1992; Sprosen et al., 1997) or greater (Loiseau et al., 2001) than that from N fertiliser grass only swards. However, the risk of nitrate leaching following heavy rainfall is greater from the pulse of N available after fertiliser application than it is from the steady release of N from clover residues in the soil (Ledgard et al., 2009). The main factor influencing nitrate leaching from grazed grassland is stocking rate. As stocking rate increases, nitrate leaching tends to increase. It has been shown in many studies that urinary N makes a much greater contribution to NO3-leaching than does fertiliser N (Ledgard et al., 2009), with urine typically contributing 70-90% of total N leached (Monaghan et al., 2007). Management strategies which reduce the number of grazing days can reduce nitrate leaching; these include moderate stocking rates, including a hay or silage harvest from paddocks (Decau and Salette, 1994) and restricting access to grazing area, particularly in wet conditions. Restricted access to grazing area has been shown to not reduce milk production or dry matter intake of dairy cows (Kennedy et al., 2009). Benoit and Simon (2004) reported that there is no evidence of pesticide contamination of water under grassland. Locating grassland in watershed areas provides a means of reducing water contamination by pesticides (Benoit et al., 1995; Mignolet and Benoit, 1999).

3. **Climate change and carbon sequestration**

Agriculture contributes approximately 11% of total greenhouse gas emissions in the EU, ranging from 6% in Germany to 34% in Ireland. While agriculture only contributes approximately 2% of carbon dioxide (CO2), it accounts for over 50% of total nitrous oxide (N2O) and nearly 45% of methane emissions (CH4). Livestock enteric fermentation, manure and inorganic fertilizer account for the major share of agricultural GHG in most EU countries. While there is no estimate of agriculture’s role as a sink for GHG, a number of studies have shown the extent of changes in farm management practices and land use affect net GHG emissions from agriculture. Land use change and forestry account for 18% of global greenhouse gas emissions (Rosegrant et al., 2008). Generally net CO2 emissions from agriculture increase when land is converted from grassland to arable crop production. Most agricultural CH4 emissions are from livestock and manure. Mitigation options include increasing animal production on a livestock unit basis, using animals that are efficient at converting feed to product or reducing animal numbers. Reducing animal numbers may not be economically feasible if total production reduces as a consequence. Diet
composition can also influence CH$_4$ emissions, for example the addition of supplementary fat to diets has been shown as an effective means of reducing CH$_4$ emissions (Martin et al., 2010). Grazed grass results in lower CH$_4$ emissions per cow per day (251 g CH$_4$/cow/day), per kg milk solids produced (174 g CH$_4$/kg milk solids) and per kg DM intake (18.06 g CH$_4$/kg DM intake) compared to a total mixed ration (TMR) diet (+146 g CH$_4$/cow/day, +26 g CH$_4$/kg milk solids and +2.2 g CH$_4$/kg DM intake) (O’Neill et al., 2010). The composition of the grass sward can also influence methane emissions. Wims et al. (2010) demonstrated that feeding lactating dairy cows on high quality low herbage mass swards can reduce CH$_4$ emissions per cow per day (282 g CH$_4$/cow/day) and per kg milk solids produced (203 g CH$_4$/kg milk solids) compared to cows grazing high herbage mass swards with lower quality (+21 g CH$_4$/cow/day and +26 g CH$_4$/kg milk solids). McCaughey et al. (1999) reported higher methane emissions from lactating beef cows grazing 100% meadow bromegrass than Wims et al. (2010) reported from dairy cows grazing swards containing 85-95% perennial ryegrass. Boadi et al. (2002) reported that beef steers grazing high quality pastures early in the grazing season produced 44% and 29% less CH$_4$ emissions than in the middle and late in the grazing season, respectively. Alcock and Hegarty (2006) modelled the effect of improving pasture quality on CH$_4$ emissions per kg liveweight on sheep farms in Australia. These authors reported a small reduction in CH$_4$ emissions per kg liveweight; however, animal numbers per hectare in this study were increased due to increased availability of herbage. Beauchemin et al. (2008) suggest that improving pasture while maintaining stocking density warrants investigation as a means of reducing CH$_4$ emissions from grazing systems.

Increasing the area of long-term grassland by reducing short term leys, arable crops and maize is an option to increase C sequestration, as is maintaining existing permanent grassland, particularly on peat soils which are an important C sink (Freibauer et al., 2004). Although grasslands can be a source of GHG emissions, their soils and associated vegetation are an important sink for C, particularly in the form of soil organic C (Peeters and Hopkins, 2010).

Incorporating legumes into grassland swards reduces the requirement for fertiliser N (and concentrate N) through the fixation of atmospheric N, as well as reducing the energy required to manufacture and transport chemical N (Peyraud et al., 2009). Approximately 55 MJ, mainly coming from fossil energy sources, are necessary to produce, transport and apply 100 kg inorganic N (Peyraud et al., 2009), while yield benefits of grass clover swards can be equivalent to chemical fertiliser N inputs of 150 to 250 kg/ha. Wood and Cowie (2004) estimate that between 3 and 7 kg of CO$_2$ equivalents are required to produce 1 kg fertiliser N. Theoretically, if a grass clover sward fixes 200 kg N/ha/year, and 7 kg CO$_2$ equivalents are emitted per kg N manufacture, the grass clover sward could prevent CO$_2$ emissions of approximately 1.4 t CO$_2$/ha/year (Peeters and Hopkins, 2010), not including transport and spreading of N. In a review of nutritional strategies for methane abatement, Beauchemin et al. (2008) reported that the inclusion of forage legumes in pasture usually, but not always, results in lower CH$_4$ emissions than from animals fed predominantly grasses, often explained by the presence of condensed tannins, lower fibre content, higher DM intake and faster rate of passage through the rumen.
The potential of soils to store C varies greatly and depends on their existing soil organic C store, C storage capacity and potential for C sequestration. Incorporating non-grass vegetation such as shrubs and trees into grassland landscapes can increase the potential C storage (Peeters and Hopkins, 2010), as well as adding to the landscape. Wildfires in grassland can also contribute to CO$_2$ emissions, and should be avoided/prevented. At a minimum, existing soil organic C accumulations in permanent grasslands and wetlands should be maintained (Peeters and Hopkins, 2010) by avoiding ploughing and drainage of these areas. Necpalova et al. (2011) reported an annual C sequestration rate of 5.74 ton C/ha over a 9 year period on permanent grassland containing clover a poorly drained gley (90%) and grey brown podzolis (10%) soil.

Soil management is key to C sequestration (Liu et al., 2006) with soils containing approximately twice as much C as the atmosphere (Powlson et al., 2011). Soils can be managed to sequester additional C from the atmosphere and thereby mitigate against global warming through GHG emissions. Soils that are building soil organic C stores are best placed to sequester C. Permanent grassland soils that are not cultivated, or are cultivated periodically only are best placed to do this. Soils can increase soil organic C content by increasing soil organic matter content, slowing decomposition of soil organic matter and through additional photosynthesis by surface vegetation and transfer of this photosynthate to the soil (Powlson et al., 2011). Manuring of soils, or other land management changes, to increase soil organic C content cannot necessarily be considered a means of increasing soil organic C content but rather a transfer of C from one location to another. Subsoils generally contain less C than topsoil and so the incorporation of deep rooted plants into grassland could be considered as a means to transfer C via the roots to the subsoil. A balance between sequestration activities and agricultural production systems is important. In many cases incorporating organic C into the soil will result in benefits such as improved soil quality and hence crop yields, there can be trade offs (Smith et al., 2007).

There is a general assumption that locally grown food is more sustainable because it has reduced transport costs compared to imported food (The Government Office for Science, 2011). This is not necessarily true. The sustainability of food production should include a full life cycle analysis of the cost of production, both up stream and down stream, including energy required to produce the food. Methane and N$_2$O emissions are produced within the farm gate and beyond the farm gate. Energy use must be considered within the farm gate, in product transport, processing and preparation, storage and retailing. Emissions are also associated with food waste. The contribution of agriculture to GHG emissions can vary depending on the boundaries of the assessment. Smith et al. (2007) and Stern (2006) concluded that agriculture, including fertiliser production, contributes 10-12% of the global GHG emissions in converting land to food, while this increases to 30% or greater when land conversion and costs outside the farm gate are included. It is estimated that 31% of GHG emissions in the EU-25 are associated with food production (European Commission, 2006). Although there is plenty evidence in the literature that animals fed on concentrate diets produce less methane per kg of product than do those grazing grass, when the conversion of land from grassland, rangeland or forestry to arable land for production of cereals and protein is considered, as well as the harvesting, processing and transport costs, the GHG emissions per kg product rises dramatically compared to grass based systems. In a life cycle analysis (including on-farm and off-farm
emissions) of grass based and confinement milk passed production systems by O’Brien et al. (2011) emissions from the confinement system had 18% greater global warming potential (kg CO₂ equivalents) per tonne of milk solids produced than did the grass based system. Total non-renewable energy use was on average 73% lower for the grass-based system relative to the confinement system when estimated per tonne of MS produced.

4. Grassland and biodiversity
There is increasing focus on the relationship between agriculture and biodiversity, both of which are inexorably linked. The impact of agriculture on biodiversity is largely determined by the expansion (or contraction) of farm land area and the intensity of production in terms of input use and farming practice. The main agents impacting negatively on biodiversity within the EU since the early 1980’s include both increases and intensification of crop production, greater use of inputs and less diversified crop rotation, i.e. an increase in wheat, oil crops and a reduction in secondary cereals such as oats and rye. The area of permanent pasture in Europe has been in constant decline since 1975 (Eurostat, 2006). This decline sometimes involves the ploughing up of meadows leading to the removal of habitat features such as hedges and other field boundaries. The overall consequences of these changes are an increase in diffused pollution through the greater use of chemicals inputs, and the removal of habitats to the detriment of wildlife. For example, butterfly populations across Europe are threatened due to changes in habitat and increasing isolation of sites within intensively managed landscapes (Thomas et al., 2001; Bourn et al., 2002). Van Dyck et al. (2009) report a decline in butterfly numbers across Europe but did not directly reveal the causes of the decline; they do however, hypothesise likely contributing factors including intensification of land use, nitrogen pollution level, declining nectar supply due to declining abundance and distribution of wildflowers, and rapid ecological changes in the wider landscape. Van Swaay et al. (2006) reported that in Europe the populations of grassland butterflies have declined in recent times at a rate of 0.8% per year, while farmland bird populations are declining at a rate of 1.5% per year. Farmland bird populations have declined severely across most of Europe in the last 30 to 40 years (Donald et al., 2001). Changes in crop and livestock husbandry practices have reduced the suitability of habitats for birds, as well as reducing the availability of food. Drainage of wetland areas and subsequent intensive management has reduced the availability of habitats for wading birds (Rhymer et al., 2010).

Semi natural grasslands are recognized as important sources of biodiversity in Europe. Generally, natural and semi-natural grasslands are found in extensive, low stocking rate livestock production systems across Europe. The composition of these swards varies widely from region to region. They support considerable botanical diversity at a local scale, providing habitats for invertebrates and other fauna (Hopkins and Holz, 2006). Periodic defoliation of extensive grasslands is vital for controlling succession of plants (Rook et al., 2004); on the other hand frequent defoliation (intensive grazing) suppresses the growth and development of seedlings of shrubs and trees and promotes the growth of grass species (van Braeckel and Bokdam, 2002). In grazing terms, diverse swards generally have a range of grasses, legumes and herbs present. While these have benefits in terms of biodiversity and provision of habitats for fauna they can result in difficulties for ruminant production systems in terms of constancy of herbage production (feed supply) and herbage quality.
Agri-environmental schemes have been introduced across Europe to counteract the effects of intensification. Positive effects of these on biodiversity have been observed. For example Bracken and Bolger (2006) found that in Ireland ‘set-aside’ areas have beneficial effects on bird populations on arable farms. McMahon et al. (2010) found that, in contrast to the expected relationships between sward botanical and arthropod richness and farm system, total arthropod abundance was significantly greater in more intensively managed swards of dairy farms compared to non dairy farms. Bird populations also benefit from maintenance and management of hedgerows on intensively managed dairy farms due to greater abundance of invertebrates for feeding (Atkinson et al., 2005; McMahon et al., 2010). Irish dairy farms, as well as farms across the EU, in general retain their field boundaries and hedgerows, providing a habitat for invertebrates, birds and other fauna.

Farruggia et al. (2010) showed that continuous grazing of diversified grassland at a low stocking rate in an upland region of central France gives similar milk production, on a per cow basis over a lactation, to a higher stocking rate rotationally grazing. The low stocking rate is also more compatible with maintaining biodiversity. Grazing animals can further contribute to biodiversity by grazing herbage and allowing light to the base of the grassland swards which can encourage the germination and growth of seeds present in the soil. Grazing animals disturb the soil surface and may bring seeds close to the soil surface, allowing them to germinate. Grazing animals can also transport seeds from one area to the other through faecal excretion, and the deposition of animal manure can provide nutrients to grassland. In multispecies swards or swards rich in diverse species of flora, animals tend to be selective in their grazing, and chose plants, or plant parts, which can best meet their nutritional requirements. In swards with little or no diversity, animals graze less selectively, although there is still some selection, as animals, particularly cattle, will reject less palatable areas of the sward, e.g. urine and faeces patches.

5. **Soil quality**

Soil is essentially a non-renewable resource. It is a very dynamic system which performs many functions and delivers services vital to human activities and to the survival of ecosystems. The soil resource base is a critical component of agro-ecosystems and must be managed sustainably (Killham, 2011). Soil functioning is fundamental or contributory to virtually all of the provisioning regulating and cultural services identified in the Millennium Ecosystem Assessment (http://www.millenniumassessment.org/en/Framework.aspx) (Powlson et al., 2011). Soil and soil fertility loss worldwide is caused by salinisation, desertification and mismanagement. Management strategies including minimum tillage, nutrient recycling, residue management and incorporation, contour ploughing and silvopastoral approaches have been and will continue to be important in maintaining and increasing soil organic matter content, and reducing soil erosion and loss.

Soil is a biologically active complex mixture of weathered parent material, organic matter, organisms, air and water which provides the foundation for life in terrestrial ecosystems. A soil incorporates expressions of the local climate as a non-solid, liquid or gaseous phase within the solid framework. In part, the air, water, and temperature regimes are influenced by the arrangement of soil particles. More significantly, they are important, independent soil characteristics, expressing the ‘climate’ of the soil. In
many instances or localities, the nutrient uptake from a soil is limited by insufficient or an excess of water, oxygen (O$_2$) deficiency or impeded root proliferation due to high bulk density. With impeded water movement, moisture deficiency may become the main limiting factor in plant growth. In the case of soil air, restriction of the exchange of O$_2$ and C may reduce the plant root’s ability to translocate nutrients to the leaves. Low O$_2$ concentrations may also retard the development of nitrifying bacteria, as a consequence soil N remains as unavailable protein instead of breaking down to release ammonium (NH$_4$) and nitrate ions (NO$_3$) (Pitty, 1979).

Soil also plays an important role in the filtering of rainwater as it infiltrates into underground reservoirs, lakes and rivers from which we extract our drinking water. The landscape which surrounds us is defined by soil as certain soil types lend themselves better to different land uses.

Mechanical damage to soil structure occurs as a result of heavy machinery and shorter crop rotations (Poesse, 1992). Compaction is now a major limitation on the productivity of many soils, particularly where chemical and biological unbalances are readily corrected with chemical additives. Compaction by trucks at harvest can almost double the energy required for subsequent ploughing. Tyre traffic may reduce air voids to the critical 10% or less and hydraulic conductivity may be severely restricted. Soil compaction can also occur due to animal treading (Herbin et al., 2011; Menneer et al., 2004) and recovery of soils from treading/compaction varies depending on a range of factors including depth of treading, stocking rate and soil moisture content. Soil compaction has important hydrologic implications in terms of its contribution to reduced plant growth, reduced infiltration rates, and increased runoff potentials (Gifford et al., 1977). Therefore, excessive compaction has damaging consequences for agriculture and the environment but compaction is not always harmful. Indeed, some compaction may be needed to improve the soil as a medium for seed germination and moderate compaction may reduce erodibility (O’Sullivan and Simota, 1995).

6. **Nutrient use efficiency**

Nitrogen fertiliser plays a vital role in agricultural productivity. It is estimated that without the use of N fertilisers that enough food for just half of the current population can be supplied with sufficient food energy and protein (Dawson and Hilton, 2011). The use of N fertiliser in agricultural systems is one of the biggest contributors to GHG emissions through the manufacture of N fertilisers and N$_2$O emissions. Increasing the precision of application and more timely application of N fertilisers is desirable, as is the recycling of on-farm sources of N such as slurry, farm yard manure and in the case of dairy farms, dirty water. The incorporation of plants with low N demand into grassland systems, or legumes which can fix N and contribute to the N economy of a grassland system is also desirable.

Incorporating white clover into grass based systems offers opportunities to increase N supply into a sward through N fixation, increased herbage production and quality, and reductions in nitrous oxide emissions. White clover (*Trifolium repens*) is the most important legume in grazed pastures in temperate regions. It grows very well in association with grasses and is tolerant of grazing (Whitehead, 1995). It also grows over a fairly wide range of climatic conditions and its herbage has a high nutritional quality for livestock (Whitehead, 1995). Perennial ryegrass white clover swards can
make an important contribution to the future sustainability of ruminant production systems in Western Europe (Peyraud et al., 2009). They have the potential to reduce N input from purchased chemical fertiliser and concentrate through the fixation of atmospheric N, as well as reducing the energy required to manufacture and transport chemical N. White clover offers farmers the opportunity to reduce fertiliser N inputs, which has both economic and environmental benefits. Forage legumes can also reduce NO$_3^-$ leaching to some extent in grass based ruminant production systems (Peyraud et al., 2010). Ledgard et al. (1999) showed that intensively managed grass clover swards can reduce farm surplus N and are relatively efficient at converting N$_2$ fixation into milk (N surplus of 23% compared to systems receiving 200 kg N/ha (44%) and 400 kg N/ha (54%), and milk output was approximately 83% that of the N fertiliser treatments).

Multi-species swards present challenges for ruminant production systems in terms of maintaining well balanced mixtures, as well as having a tendency to lose key species from the swards (Guckert and Hay, 2001), hence the prevalence of monoculture fertilised grasslands in intensive grassland ruminant production systems. Incorporating legumes into grassland can have many beneficial effects on sustainable grass based ruminant production system, including reduction of purchased N fertiliser and high feeding quality (Peyraud et al., 2010). Kirwan et al. (2007) and Lüscher et al. (2008), in a European project undertaken at 28 sites in 17 countries, showed that grass legume mixtures with four species had yield benefits over those species sown in monoculture. Inclusion of clover in swards also has benefits in increasing feed quality of herbage, particularly in mid-season when grasses are in the reproductive stage and are generally less digestible than in spring and autumn due to high reproductive stem content. Mixed grass white clover swards can increase dry matter (DM) intake and milk yield (Riberio-Filho et al., 2003; 2005) relative to grass only swards. Higher DM intake on grass white clover swards is largely due to the greater digestibility of white clover as a result of reduced structural components (e.g. cellulose, hemi-cellulose and lignin) compared to perennial ryegrass.

Peyraud et al. (2010) estimate that herbage net energy produced per MJ of non-renewable energy consumed is 3 times greater on grass white clover swards compared to fertilised grass swards (17.7 KJ NE vs. 5.7 kJ NE/MJ non-renewable energy). Basset-Mens et al. (2009) reported that energy consumption per kg milk produced is 59% lower on systems applying no fertiliser N compared to those applying 140 kg N/ha in New Zealand. The total energy consumption per kg of milk as calculated using life cycle analysis (LCA) and IPPC methods is twice as high in Europe where there are large amounts of fertiliser and concentrates used compared to New Zealand where there is greater reliance in grass-clover swards (Basset-Mens et al., 2005).

### 7. Food quality and safety

Consumers have a demand for consistent food product quality. European consumers in particular have concerns about food quality and safety and tend to view grass based milk and meat systems being as sustainable, safe and delivering high quality product. Animal nutrition affects the quality and nutritional value of dairy (Downey and Doyle, 2007) and meat products (Dunshea et al., 2005). Feeding strategies must be designed to meet animal energy requirements, while controlling feed costs (Purvis et al., 2012). The diet of ruminant animals can affect the taste and the chemical composition of meat and dairy product produced, and can have consequences for human health.
(Hopkins and Holz, 2006). The link between saturated fat consumption and cardiovascular disease has resulted in considerable focus on the fatty acid composition of products from ruminants. Coakley et al. (2007), Wyss et al. (2010) and Butler et al. (2011) all report increased levels of conjugated linoleic acids, vaccenic acid, and omega-3 fatty acids in milk from grass fed cows. Ostrovsky et al. (2009) found levels of conjugated linoleic acids and vaccenic acid in grass fed ewes milk three times greater than ewes fed a total mixed ration, and twice as much omega-3. Beef from cattle fed grass based diets has also been shown to be higher in unsaturated fats, especially omega-3 and rumenic acid, than cattle fed indoors on concentrate and conserved forage diets (Priolo et al., 2001). Lind et al. (2010) reported that the fatty acid composition of meat from lambs fed concentrate for more than four weeks prior to slaughter was changed unfavourable with respect to human dietary requirements. Milk from cows on largely grass diets is higher in vitamins A and E than from other cow diets (Martin et al., 2004).

Food safety is of increasing concern as the food supply chain lengthens. Food safety concerns in recent years have included outbreaks and spreading of animal diseases including BSE, Blue Tongue, Foot and Mouth Disease, Classical Swine Flu and Avian Influenza. Food scares due to chemical contamination (e.g. melamine contamination) and the presence of banned substances such as dioxins in animal feeds. There are multiple factors contributing to these food safety problems, including reduced EU import controls (Purvis et al., 2012) and the lengthening of the food chain. As the length of the food chain increases the sharing of knowledge, trust and understanding between farmers, processes retailers and consumers declines and ultimately ceases. International markets often result in an absence of transparency, accountability and traceability and as a result consumer confidence is hugely undermined. As a result across Europe there is increasing demand for locally produced and origin labelled products using local flora of various sensory characteristics to produce meat or cheese (Coulon et al., 2004; Priolo et al., 2001). European legislation now contains ‘the farm to fork principle’. By applying this principle there is some assurance that the quality and safety of the food product in the supply chain from producer to consumer can be assured. However, a large proportion of raw materials, especially for animal feeds, come from outside the EU and hence there is a requirement for policy to ensure the safety of these products. Increasing the quantity of grazed grass in the diet of ruminant animals for milk and meat production reduces the requirement for raw materials purchased outside of the EU. Labelling, traceability and quality assurance schemes all contribute to assuring the authenticity, quality and safety of grass based products. In recent years, techniques have been developed to discriminate between products of grassland production systems and other production systems (Monahan et al., 2010), although these techniques are not yet in widespread use.

8. Animal health and welfare

There is a general perception that the welfare of grazing animals is better than that of housed animals or animals on intensive feed lots. Grazing animals generally are not restricted in terms of space and have free access to exercise and roaming. Corazzin et al. (2010) reported that dairy cows usually housed in tie-stall barns and mountain grazed during the summer had reduced lameness compared to the counterparts housed during the summer. Grazing animals also had a reduction in injuries, coughs and rising duration compared to the indoor cows, although there was an increase in vulva
discharge (indication of reproductive disorders). Braghieri et al. (2011) measured potentially higher disease susceptibility and lower welfare of podolian beef bulls kept indoors compared to free ranging counterparts. Grazing of livestock and the resultant exercise reduces incidences of lameness through better claw confirmation as a result of exercise and claw trimming and reduced presence of lesions (Corazzin et al., 2010) compared to housed animals receiving no exercise (Loberg et al., 2004; Corazzin et al., 2010). Leaver et al. (1988) reported that the prevalence of lameness is low during the grazing period. Hernandez-Mendo et al. (2007) observed that lame cows turned out to pasture showed improved gait faster relative to a comparable group housed in a free stall barn. Benefits of grass based systems in terms of lameness must be considered with caution as in certain circumstances such as when cow tracks are not maintained in grass based production systems incidence of lameness can still be high (Lean et al., 2008).

Only about 10% of the world’s milk is produced from grazing (World Animal Review, 1995); as a result most dairy cattle have not been selected under grazing. Reduced fertility in dairy cows, due to long term selection for milk production characteristics particularly for intensive indoor milk production systems has resulted in reduced fertility, extended calving intervals and reduced life time productivity of dairy cows. In contrast the majority of beef cows are managed on seasonal grass based systems and therefore it is less likely that there will be interactions between genotypes and environments in terms (Buckley et al., 2005). Whether fertility should be considered as a component of animal health is debatable but it is one of the main issues impacting on animal production and farm profit across Europe. In intensive grass based ruminant production systems requiring seasonal calving good reproductive performance is essential. There is now evidence that animals selected based on high concentrate diets have poorer reproductive efficiency and cannot express full genetic potential for milk yield in a grass-based environment (Buckley et al., 2005; Horan et al., 2004; Macdonald et al., 2005; McCarthy et al., 2007).

Successful grazing systems require breeds/strains that are adapted to achieving a large intake of forage relative to their potential milk yield, are fertile and healthy; have good conformation to walk long distances and high survivability (Dillon et al., 2007; Buckley et al., 2005). Recent studies have shown large difference in performance (especially in relation to fertility and survival) and overall farm profitability between divergent stains/breeds of dairy cows when compared on a grass-based system compared to a high concentrate system (McCarty et al., 2007). The development of sustainable grassland-based ruminant production systems clearly requires the most adapted animal genetics. Dual-purpose dairy cow breeds usually have better milk composition and beef merit. In grass-based systems, crossing the Holstein-Friesian with an alternative dairy breed sire can provide producers with an alternative to increase overall animal performance by increasing herd health, fertility and milk value through hybrid vigour (Lopez-Villalobos, 1998). Similarly beef cows from large, late maturing breeds are more restricted by inadequate nutrition than smaller early maturing breeds.

Allowing animals to graze outdoors in groups permits social contact and allows the selection of the hierarchy of the herd. Housing dairy calves in groups also allows them to engage in natural social interactions, but when poorly managed, this can lead to increased incidence of certain diseases or aggression (von Keyserlingk et al., 2009).
Washburn et al. (2002) in a review reported that there are several examples in the literature that show that access to pasture can improve aspects of cow health such as mastitis.

9. Grasslands and Landscape
Another function of grasslands is that they contribute greatly to the landscape. Farmed land and non-farmed land are very tightly interlocked. Grassland and the ruminant production systems present all have a role to play in defining the landscape in which they exist. A wide range of landscapes are influenced by grassland, from productive grassland (e.g. south of Ireland; Brittany, France; parts of the UK) to Alpine (e.g. Switzerland, parts of France) to rough grazing ground (e.g. in parts of the west of Ireland), and mountain grassland and low land nutrient poor grassland. Urban dwellers have an expectation of ‘green’ areas, provided by grasslands, in the country side. Tourism and outdoor recreation can have direct economic advantages for rural areas where scenic landscapes, wildlife and biodiversity exist and have been conserved (Hopkins and Holz, 2006).

Conclusions
The supply of agricultural products and ecosystem services are both essential to human existence and quality of life. However, recent agricultural practices that have greatly increased global food supply have had inadvertent, detrimental impacts on the environment and on ecosystem services, highlighting the need for more sustainable agricultural methods. The goal of sustainable agriculture is to maximize the net benefits that society receives from agricultural production of food and fibre and from ecosystem services. This will require increased crop yields, increased efficiency of nitrogen, phosphorus and water use, ecologically based management practices, judicious use of pesticides, and changes in some livestock production practices.

The advantages of grass based ruminant production systems in the maintaining sustainable agriculture are many including positive effects on economic sustainability, product quality and human nutrition, animal welfare, landscape management, maintenance of rural populations, reductions in GHG emissions compared to confined systems, increased C sequestration due to permanent or semi permanent state of grassland, soil protection, biodiversity and water quality. However, there are limitations associated with grass based systems. In particular, variable feed composition of multispecies swards and lower stocking rates than in confinement systems can reduce product produced per hectare; not all ruminant species/strains are suitable for extensive grass based systems; grazing can have a negative impact on soil structure, and on water quality; intensification of grazing systems can reduce biodiversity.

The challenges for MULTISWARD are to ensure that management strategies can be developed to maximise ruminant production from grass based systems while ensuring that grassland continues to provide ecosystem services and improve the manner in which these are delivered. Particular focus should include increasing biodiversity within the farm, while maximising economic return to the farmer through animal output; increasing nutrient use efficiency and reducing GHG emissions from grass based ruminant production systems; selecting the right animal for grass based milk production systems; strategies to increase the proportion of grazed grass in the diet of ruminant animals, taking cognisance of the wider ecosystem and environment.
Literature Cited


