AUTOGRASSMILK Report Summary
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Final Report Summary - AUTOGRASSMILK (Innovative and sustainable systems combining automatic milking and precision grazing)

Executive Summary:
Dairy farming has adopted automatic milking (AM) at an accelerating rate in many EU countries for reasons such as improvement in lifestyle, less physical work, attracting skilled labour and lower labour costs. The defining feature of AM systems is that the cows come voluntary to the milking unit and milking is evenly distributed over a 24 hour period. Up to now, indoor feeding systems have been well adapted to AM, however grazing has not, thus leading to a decrease in grazing on farms with AM. Grazing has many advantages for economy, environment, animal welfare and product quality. With increased focus on sustainability it is essential that dairy systems with new precision grazing technologies are developed in which grazing and AM can be integrated.

AUTOGRASSMILK was a unique cooperation of 6 SME-AGs and 6 RTDs, with one of each based in Ireland, Denmark, The Netherlands, France, Belgium, and Sweden, more than 30 monitor farms across those countries and two partner farms in Ireland and Denmark. The specific objectives of AUTOGRASSMILK were addressed through 5 work-packages and included (1) developing feeding strategies for dairy cows incorporating grazing with AM; (2) using new precision grazing technologies to optimise the integration of grazing and AM; (3) increasing the sustainability of integrated grazing and AM technologies; (4) developing a tool that will allow dairy farmers to optimise economic efficiency when combining grazing with AM and (5) continuously disseminate new technology to end-users in a form that is easily accessible and locally adapted to improve farm efficiency.

Various strategies have been developed to maximize milk output from integrated grazing and AM in a wide range of production conditions, from pasture-based extensive systems with low feed costs, to intensive systems with only small amounts of pasture in the diet, aimed at high milk yield per cow. Recommended feeding strategies for periods of grass inadequacy as well as performance of different cow breeds were also investigated. A new automated grass measurement tool was used to ensure the precision required in grass allocation, particularly important in integrated grazing and AM systems. Guidelines have been developed for the successful operation of both automated carousel (rotary) and mobile milking systems. Such systems are particularly suited to farms with large herds and with fragmented land bases, respectively. The construction of a web-based sustainability tool, based on the findings of this project, can help the farmers (with help from their advisors) to understand and increase the sustainability of their farms. The reports and the material available on the web-site can be used in the awareness of an integrated assessment of sustainability. The development of a further web-based decision support tool will assist farmers and advisors in north-western Europe in the decision-making process around grazing and AM systems from an economic perspective. It allows more informed decisions to be taken by farmers. It also provides direct access to relevant topics, research results, practical experiences and links to other relevant interactive internet tools. A significant focus of the project has been an awareness of the importance of dissemination, i.e. making research results and accumulated knowledge accessible to the SME-AGs, their members, the wider group of farmers, extension personnel, the scientific community and policymakers. The website was launched in March 2013. A range of information relating to cow grazing and AM has been published (in the different national languages) on the website. National events have been published on the website’s Events list. Presentations delivered by project RTD and SME-AG representatives at conferences, seminars and workshops have also been uploaded. The regular updating of the website has been an important on-going task.
AutoGRASSmilk has provided the means to long-term impacts such as increased productivity in AM herds with grazing and increased numbers of AM system herds considering grazing as a realistic opportunity.

Project Context and Objectives:
The introduction of automatic milking (AM) systems has created a significant change in herd and farm management. The main features of AM are (i) cows volunteer themselves for milking (ii) milking is distributed over a 24 hour period and (iii) milking is conducted without human presence. Since commercial introduction in 1992, AM has become increasingly popular in North West Europe. It is considered that there are more than 10,000 commercial farms using one or more AM systems, within EU countries, with up to 30,000 AM units globally. Potentially up to 50% of cows in new facilities within the EU will be milked by AM systems by 2020. AM has transformed the process of milk production on dairy farms, significantly reducing the physical work involved, enabling farmers to give more time to planning and strategic decision-making. Automatic milking has a number of advantages over conventional forms of milking. These include a potential reduction in labour input, increased milk production and improvement in cow well-being. Cows can be milked more frequently without extra labour costs and with consistent milking routines. Conventional milking takes up a significant amount of the total labour input required to operate a dairy farm. A New Zealand study found that for a sample of farms with <190 cows, milking took 3.8 to 4.8h per day. A study conducted in Europe, showed that AM reduced labour hours by 20%. A further study in 2011 reported a 40% reduction in labour hours for organic dairy farms. An increase in milk production per cow is usually observed with AM, although this has been found to be highly variable, ranging from -6% to +35%. This may be explained in part by the galactopoietic effects arising from an increased frequency in milking and partly by the more frequent opportunity to feed concentrates. Other potential benefits of AM include reduced stress on cows during milking and a decrease in lameness. It is widely reported anecdotally that the use of AM leads to a reduced fear of people for cows and a generally quieter cow temperament. The main challenge that currently confronts the use of AM is the difficulty experienced in incorporating the use of pasture into this milk production system.

Grasslands are an essential component of sustainable farming systems, and are acknowledged as having a multifunctional role in food production and environmental sustainability. There are many advantages associated with grass-based systems from an environmental, animal welfare product quality and economic perspective. Grassland cultivation results in lower nitrate-nitrogen leaching losses than arable crop production, particularly in the case of maize silage. Grassland is associated with the preservation of soil organic matter. Increasing this improves soil fertility, water-holding capacity and the long-term stabilisation of soil structure and decreases soil erosion and sequesters carbon from the atmosphere. In general, infiltration capacity is higher in grassland due to the accumulation of organic matter at the soil surface and the development of an extensive root system and stable soil structure. Grassland is also associated with lower inputs of pesticides and fossil fuels, particularly where the grassland is harvested as grazed pasture. In many areas grassland is seen as having a positive impact on landscapes and being more species-rich with greater above and below ground biodiversity of fauna and flora. In terms of the important issue of milk quality it has been shown that cow grazing time improves aspects of milk quality. The grazing of dairy cows has been a long-standing tradition in north western European countries. The incentive for this practice is and was mainly economic. It was the cheapest way to feed dairy cows, involving the lowest input of labour and mechanization. However, over the last decade, the number of grazing dairy cows has decreased sharply. There are a number of reasons for this trend, but the main one would appear to be the development of large scale dairy herds, which require the complex control of feed intake outdoors and complex logistics. In addition, the relatively long walking distances from pasture to milking parlour, and the perceived increased labour demand associated with grassland management, are aspects of this form of dairy farming that have contributed to its decline. Thus, while society in general appreciates grazing animals on the landscape and values very highly the dairy products of grazed animals, there is a decreasing trend in the use of grazing by many European dairy farmers. The extent and rate of this decline is causing considerable concern among consumers and policymakers, as well as those dairy farmers who continue to use pasture as a significant component in their milk production system. Furthermore, since it is envisaged that up to 50% of cows in new facilities within the EU will be milked by AM systems by 2020, the likelihood is that grazing occurrence would decrease rather than increase in the coming years. In a parallel situation, in many regions in the EU it is now compulsory to have cows grazing for animal welfare and consumer demands especially for organic milk production, and this obviously creates a difficulty for such farms engaging with AM systems.
Thus, reduction in cow pasture grazing is even more likely to occur when AM is in place. From previous work, it is clear that grazing is practised less on farms with an AM system than on farms without an AM system. Since it is generally accepted that the dairy producing units in Europe will increasingly adopt AM systems; this will in turn result in a large-scale reduction in grazing dairy cow numbers. This is an undesirable trend. There are two related reasons for this which are specifically associated with AM. The main reason is that once cows are let out to pasture, they tend not to return to the AM unit voluntarily, especially not when distance is large. The consequence is that the dairy operator has to collect the cows on a routine basis which would add very significantly to the labour demand on the farm and partially counteract the benefit of installing the AM system. Additionally, related to the reduction in cow milking frequency is the fear of a potential reduction in cow milk yield. This arises generally because within an indoor scenario, the focus is on high milk yield per cow and relatively high (2-3) milkings per cow per 24 h period. Combination of desired high milk yield and adoption of AM are therefore gradually leading to less grazing. Thus, AM and grassland farming systems are each highly valued, but were generally considered to be incompatible in combination. AM has been associated with a decrease in grazing and is perceived as a threat to grazing based production systems.

It may be that farmers simply lack knowledge and tools to integrate a good grazing practice and AM. In many consortium countries farmers are not convinced that sufficient cow feed can be provided by grazing. Until recently the technology did not exist to measure grass allocated and consumed, and as a consequence farmers did not have the data to make informed decisions on the use of grazing with AM systems. In countries like Ireland, where grazing is the major component in cow feed, farmers have a different concern viz. that the same standards of production cannot be achieved with AM. Their major concerns are that the established economic benefits of grazing (each tonne of additional grass utilised increases farm net profit by €267/ha [French et al. 2015]) will be lost or substantially reduced if AM is used, and that the uptake in the use of AM will be limited unless it can be demonstrated that AM systems can operate successfully in grazing based systems of milk production. Thus, there was an urgent need to address the system development required to optimise pasture utilization in combination with AM.

The AUTOGRASSMILK project aimed to address these different concerns by developing and implementing improved sustainable farming systems that integrate grazing with AM in ways appropriate to the different methods of dairy farming practiced in Europe. The SME Associations (SME-AGs) initiated this proposal. They believed the integration of cow grazing and AM would address their members’ needs, and make a substantial contribution to the future of dairy farming in the EU. The SME-AGs identified the Research for the Benefit of SME Associations call of FP7 as providing an opportunity to undertake research and develop technological solutions to integrate grazing and AM in the different regions of the EC. The consortium had 15 members with 6 SME-AGs and 6 RTD Performers from 6 different counties, 2 SMEs representing two end-users on whose farms the research-based technological solutions were tested, and one SME undertaking project management. The consortium included countries where AM was widely used but mainly with cows on indoor feeding systems, and countries with well-developed systems of cow grazing but where AM was in limited use. The project aimed to address and suggest solutions to issues relating to farm labour demand, farm fragmentation where land layout was a constraint to herd expansion, legislative requirements for cow grazing times, reduction in feed costs, and consumer preference for milk produced from grazed grass.

It was in the interest of all of the SME-AGs involved to gain maximum advantage for their members. The practical nature of the research work undertaken ensured easier uptake by their members. To assist in the research element of the project and to make it relevant to SME-AG members, additional ‘Monitor Farms’ were asked to contribute by allowing data capture on their farms. Between two and six members of each SME-AG were recruited as ‘Monitor Farms’. These farms assisted in the accumulation of knowledge (for the RTD and ultimately the SME-AG) at ground level through operating as commercial dairy farm entities while being monitored closely for a number of sustainability parameters, including economics. This subsequently allowed the technology on-farm (modified by this project) to be measured and evaluated. The information could then be combined appropriately with the results from the trials conducted at the farms located at the research centres of the RTD’s.

Overall project objectives were: (1) Develop optimum feeding strategies for dairy cows incorporating grazed grass and AM for different production systems (2) Optimise the integration of AM with cow grazing using new technologies (3) Increase sustainability of integrated grazing and AM technologies (4) Develop tools to enable dairy farmers to optimise economic efficiency when combining grazing with AM systems (5) Make these new technologies available to farmers in forms that are easy to use and can be adapted to local circumstances. To achieve these objectives, the project focused on five
workpackages:

WP1: identify the optimum proportion of grazed grass in a cow’s diet for AM based production systems, develop best practice supplementary feeding strategies, and compare the AM performance of different cow breeds.

WP2: develop a Decision Support Tool (DST) to improve pasture management, evaluate animal behaviour technologies and investigate the potential of alternative AM technologies.

WP3: develop a sustainability assessment tool, identify quantifiable sustainability indicators, establish a register of monitor farms, develop a recording and analysing system for farm sustainability data, and undertake a stakeholder analysis.

WP4: provide an economic comparison of AM on dairy farms where cow grazing is practiced and farms where it is not. It will include an analysis of the financial interaction between capital investment, labour requirements, running costs and the optimization of AM integrated grazing, and the development of an economic web based DST.

WP5: address dissemination of project information and establishment of a website.

Workpackage 1 comprised of three tasks, which focused on optimum feeding strategies for cows in milk production systems incorporating AM and grazed grass. The first task (M2-M28) involved TEAGASC, SLU and was led by SLU. It aimed to maximise milk output from integrated grazing and AM production systems where grazed grass formed different proportions of cow diet. Task 1.2 (M2-M28) focused on developing best practice feeding strategies to meet variations in grass supply and quality, especially during periods of grass inadequacy. It Involved partners: TEAGASC, AU, VFL, IDELE, CNIEL, ULg, CDL, SME FARM DK and was led by IDELE. Task 1.3 (M2-M28) focused on establishing data on the optimum cow breed/type for an integrated grazing and AM production system. It was led by TEAGASC and also involved SLU.

Workpackage 2 comprised of four tasks, which focused on new technologies such as a Decision Support Tool (DST) to improve pasture management precision, evaluation of animal behaviour technologies and potential of alternative AM technologies. Task 2.1 (M1-M24) involved precision grazing management for integration with AM systems. This task was led by TEAGASC and involved partners: TEAGASC, WLR, ULg, IDELE, LTO, SME FARM IE. In Task 2.2 new grazing technologies were evaluated. It was led by WLR and involved WLR, ULg, IDELE, AU. Tasks 2.3 and 2.4 (M1-M36) evaluated the potential use of robotic AM-carousel (rotary) and mobile AM for fragmented farms, respectively. Task 2.3 involved SLU, AU and was led by SLU, while Task 2.4 involved partners ULg, IDELE, AU, CDL and was led by ULg.

Workpackage 3 comprised of four tasks, which focused on contributing to an increase in sustainability of AM milk productions systems with integrated grazing. The first task (M1-10) was to identify quantifiable sustainability indicators using a participatory analysis, based on relevant sustainability dimensions, themes and subthemes. This task was led by AU and carried out in conjunction with the partners: AU, IDELE, WUR, and TEAGASC. The second task (M10-26) was to register relevant data on monitor farms in all partner countries. SEGES was the task leader. The findings of WP 1 were used to evaluate relevance. The SME AGs were very involved in this task as they allowed direct contact with their members. The third task (M 18-36) was to analyze these data using a sustainability assessment framework based on state of the art methodology generated in this project. TEAGASC, AU, IDELE, WLR were involved in this task, with TEAGASC being task leader. Data analysis commenced after the first year of registrations was complete. The fourth task (M28-36) was to convert the sustainability assessment framework into an online tool that could be used by farmers to check their enterprise for possible strengths and weaknesses. AU, WLR, IDELE, TEAGASC, IGA, and SME FARM DK were involved. AU was the task leader.

Workpackage 4 comprised of 4 tasks and focused on economic assessment of integrated grazing and AM systems (M6-M18). Task 1 (TEAGASC, WLR, AU, LTO, CNIEL) looked at economic implications of AM and grazing. Task 2 (TEAGASC and WLR examined economic comparison of AM and conventional milking (CM) systems. Task 3 (TEAGASC, WLR, AU, ULg) investigated economic optimisation of AM through increasing cow numbers per robotic unit and Task 4 (TEAGASC, WLR, LTO, AU, CNIEL, ULg, CDL, SDA) involved development of an interactive web based decision support tool will be developed for farmers (involved development of a decision support tool (DST) to quantify the interaction of feed systems and AM systems.

Workpackage 5 addressed dissemination of project information.

Project Results:

WORK PACKAGE 1: OPTIMUM FEEDING STRATEGIES FOR DAIRY COWS, INCORPORATING GRAZED GRASS WITH AM FOR VARIOUS PRODUCTION SYSTEMES IN EUROPE.

This work package was led by the Swedish University of Agricultural Sciences (SLU) and involved the Agriculture and Food
Development Authority in Ireland (TEAGASC), Aarhus University in Denmark (AU), the Danish farmer organisation SEGES (previous name VFL), the French Institut De L'Elevage (IDEELE) and Centre National Interprofessionnel De L'Economie Laitiere (CNIEL), the Universite de Liege (ULg) in Belgium with Comite du Lait des Provinces de Liege, Namur, Luxembourg, du Brabant Wallon et Hainaut (CDL) and the SME farm from Denmark, Thure Worm.

The deliverables associated with this WP have been completed and are as follows:

D 1.1: Country specific guidelines on optimizing pasture proportion of cow diet (including periods of grass scarcity) in association with AM

D 1.2: Specific needs of different cow breed/type in relation to grazing and AM

The work package has three tasks that have been undertaken by different partners. Task 1.1 had its focus on “Maximizing milk output from integrated grazing and AM production systems where grazed grass forms different proportions of cow diet”. This task involved Ireland and Sweden. Ireland represented a country which traditionally had a high proportion of grazed grass in the cow diet, while Sweden represented a country with a low proportion of pasture in the diet. Thus, the two countries differed substantially in this respect. In Ireland, a diet incorporating approximately 90% pasture was compared to a diet with 75% pasture. In Sweden, a diet incorporating approximately 25% pasture was compared to a diet with 10% pasture. The concept is that countries with pasture diet proportions between these end points (95, 75% and 25, 10%) could interpret what proportions would be appropriate and economical under their own particular conditions. Task 1.2 was focused “Developing best practice feeding strategies to meet variations in grass supply and quality, especially during periods of grass inadequacy”. This task involved all partners except Sweden. Activities within these two tasks (Task 1.1 and Task 1.2) were reported together as they interact with each other and experiments performed may be relevant and answer elements of both questions. This is also reflected in Deliverable 1.1 which incorporates results from activities within Tasks 1.1 and 1.2. The third task (Task 1.3) had its focus on establishing “Optimum cow breed/type for an integrated grazing and AM production system”. This task involves only TEAGASC/Ireland and SLU/Sweden and is based on a more in-depth analysis of effects of breed in the experiments performed in Tasks 1.1 and 1.2. Ethical clearance was obtained by the relevant RTDs for work conducted in this work package.

The results of Workpackage 1 have mostly been presented previously in the country specific guidelines for combining AM with grazing that are found in Deliverable 1.1 and also in the analysis of the performance of different breeds in relation to AM combined with grazing that are presented in Deliverable 1.2. This final report will largely summarize these reports/deliverables that represent the core of the entire work within Workpackage 1, with the research results and the conclusions on the results obtained. As mentioned previously, the production system in Ireland is characterized by maximizing the use of grazed grass in the cow diet. However, the country has up to now had little experience of milking robots and AM systems. As Irish farmers are gaining interest in introducing AM systems on their farms, it is of fundamental importance that these farmers can be supplied with up to date research, adapted for production conditions with large amounts of grazed grass in the diet. The experiments performed in Ireland within the framework of the AUTOGRASSMILK project has therefore been extremely valuable in providing the Irish milk producing community with solutions incorporating reduced labour requirements within the prevailing low cost production system, based on pasture and spring calving. The experiments performed have focused on three main questions:

1) How to organize a rational grazing system to achieve a smooth and even cow traffic system where cows will voluntarily and regularly move to the milking unit and back out to the pasture area on a number of occasions per day. This work was performed at an early stage of the project by testing different cow traffic systems and involving expertise with experience in the field of AM and grazing in another country with a pasture based production system, i.e. New Zealand. The establishment of a functional well working grazing system at the experimental farm at Teagasc was the basis for further experimental work undertaken within AUTOGRASSMILK.

2) How to secure the nutrient demands of the cows in the transition periods in early and late season, when grass growth may not be sufficient to cover the nutrient needs of the cows and during other periods of grass inadequacy. Therefore, different levels of concentrate supplementation were studied during transition periods.

3) How to maximize the production from the system with maximum milk yield per robot, creating an optimal balance between number of cows in the system and number of milking per cow. As the robot only can handle a certain number of milking per day, the optimum balance must be attained between number of cows in the system and the number of times each cow is milked. In essence, if more milk can be obtained by having more cows in the system and milking each cow fewer times, this may be economical for the farmer, especially as grazed grass has a very low feed cost. Thus, experiments which studied cows
The first challenge of how to organize cow traffic in a pasture based system was addressed early in the project. Expertise and literature was reviewed and a system with three grazing sections A, B and C was established where the herd had access to new pasture in the A section from 00:00, new pasture in the B section was offered at 08:00 and finally new pasture was offered in C at 16:00 hours. Thus, the cows quickly learnt that at certain times of the day, they could move to a new fresh pasture and on their way to the new area, they passed the milking unit. At the time of passage, all cows with milking permission would be milked before being allowed to enter the area with fresh pasture. This type of ABC system has been described elsewhere but the establishment of the system, the demonstration of its functionality and the description of how it can be applied with regard to practical questions such as allocation of pasture, pre- and post-grazing sward heights etc. is important for farmers. Earlier, the most common system that has been described under European conditions has been the AB system where cows rotate between two grazing areas daily. Thus the demonstration and use of ABC system on the Irish research farm adds another management option that farmers can adopt when the conditions on the farm are suitable.

The second question was the question of the level of supplementation during transition periods in spring and autumn and periods of pasture shortage. Experiments that addressed this question were performed in 2014 and 2015. The results of the experiments showed that the strategies in spring and autumn differ. During springtime, the cow's nutrition and grass availability should be the main focus with regard to the amount of supplements fed. In Ireland, grass growth generally gets underway gradually from the end of February, increases in March and April giving a peak in growth rate in May-June, where after it gradually decreases until October-November. As pasture quality is high in the spring the amount of supplements offered in springtime should be entirely determined by the amount of grass that is available. The prevailing weather and pasture conditions in the particular year in combination with the level of production in the herd will determine the amount of supplements needed. Furthermore, the results of the experiments performed indicate that the management decisions on farms with AM compared to those with conventional milking do not really differ in this aspect during the early season grazing period. High levels of supplements should be avoided if possible in springtime be so as to create good sward conditions for the remaining part of the grazing season. If high levels of supplements are fed in the spring when pasture is available, pasture utilization will drop and the regrowth of grass will be compromised. In the experiment performed in spring of 2015, no significant difference in milk yield or milking frequency was observed at a low compared with a high level of concentrate supplementation. However, the conditions for supplementation in the autumn, were different. At this time of the year, grass quality is not so high and the herd does not have the same keen interest in grazing. Experiments were performed within the project in autumn time in which a high level of concentrate (3.0 and 2.65 kg/cow per day in experiments in 2014 and 2015, respectively) were compared with a lower level (0.84 and 0.5 kg/cow per day in 2014 and 2015, respectively). The higher level of supplementation resulted in a significantly higher milk yield compared with the lower level of supplementation in both experimental years, 16.2 vs 14.5 kg milk in 2014 and 12.8 vs. 10.8 kg milk/cow per day in 2015. Furthermore, milk traffic parameters were also favourably affected by a higher level of supplementation that led to a significantly shorter milking interval in both years; 13.6 vs 14.6 hours/visit and 16.4 vs. 18.0 hours/visit in the experiment of 2014 and 2015, respectively.

The third research question addressed in Ireland was the question of milking permission. In the experiment of 2013, cows in the two groups were allowed milking permission 2 and 3 times a day, and in 2014 milking permissions of 1.8 and 3.2 times a day were compared. In the first experiment there was no significant effect of milking permission on milk yield/cow per day; (19.0 vs 18.4 kg milk/cow per day for 3 vs 2 times milking permission daily, respectively). However the milking frequency was significantly higher for cows with milking permission of 3 times compared to 2 times per day (milking frequencies of 1.8 vs. 1.4 times per day for 3 vs 2 times permission per day, respectively). Milking interval was significantly lower (12.6 vs. 15.1 hours/visit) for 3 vs. 2 times permission daily. In 2014, milk yields of 15.0 and 15.7 kg milk/cow per day were associated with milking permission of 1.8 and 3.2 times per day, respectively. Significant differences in milking frequencies of 1.3 and 1.9 milkings per day and significant differences in milking intervals were observed for the corresponding cow groups. However, it may be concluded that the differences in milk yield were not so large, so it is probable that lower milking permissions combined with a higher number of animals in the system is economical in production systems with large proportions of pasture in the diet such as the Irish situation.

The research in France has been performed in two different sites with different conditions and different production systems: In Brittany, the objective was to establish an AM system based on maximizing pasture as far as possible in the cow diet. Farm
fragmentation is a major problem in many locations. The suitable grazing areas are often not situated in the vicinity of the farm and public roads separate the milking and feeding areas from the grazing areas. As dairy cows need to be milked daily, it is common that grazing is minimized or not practiced at all. The problem with fragmentation becomes especially serious for farms with AM, as cows are milked continuously over the day and night period and when AM is combined with grazing, this requires a continuous flow of cows coming and going between the barn and the pasture throughout the day and night. Therefore, a mobile milking unit was developed at the research farm Trevarez in Brittany (see work package 2) and this mobile milking unit was used at the research barn. The preparation and establishment of a mobile automatic milking unit is described in detail in the report from work package 2. However, experiments have been performed at the experimental farm throughout the process. As in the case of Ireland, the main goal was to maximize the amount of pasture in the diet. This is also the most sustainable production method for organic production. However, variations in pasture supply make it necessary to establish a flexible management system to deal with periods of pasture shortage. Several management systems have been tested and evaluated at the experimental farm in Brittany, with focus on practical solutions.

Early and late in the season, during transition between winter feeding and pasture, the herd has been kept at the winter site and allowed to graze the surrounding fairly limited pasture area while receiving supplements to cover the nutrient needs of the animals. In 2013 the mobile automatic milking could not be transferred to the summer site as the latter was not ready to welcome the robot; the herd had to be kept at the main barn “winter site” all summer. Initially after pasture let-out the herd was kept in a day and night grazing system with 1 paddock per 24 hours. This proved unsatisfactory as cows did not voluntarily go to the milking unit often enough, the milking frequency rapidly dropped from 2.3-2.5 in the winter to 1.9 and milk production dropped. Therefore, after a few weeks, a grazing system with two paddocks A and B was established and cow traffic became smoother with an increase in milking frequency and a more even distribution of milkings over the day and night period. In the subsequent year (2014), the mobile milking unit and the platform on summer site were completed and the unit and herd were moved from the winter to the summer site when pasture growth was sufficient to support milk production on pasture only with a minimum amount of concentrates at milking. The grazing system at the summer site was a system with two grazing areas A and B and the herd moved daily from the one area to the next to get new pasture. In the process of transition between pasture area, all cows passed the milking unit and were milked if they had milking permission. The results in this system were very satisfactory with a milking frequency of 1.8 and a yield of 18.6 kg per cow per day. Furthermore, the cows were able to stay in the summer site until October 20th and the following transition period at the winter site with both pasture and silage lasted until 8th of December. In the last experimental year, a grazing system involving 3 grazing sites (A; B and C) was tested. The weather conditions this year led to a shortage of pasture in mid-season and the cows were then transported to the “winter site” where supplementary feed was given on July the 1st. When conditions improved the herd could be transferred once more to the summer site on August 18th and they stayed there until November 3rd. The different weather conditions in 2014 compared with 2015 did not allow a comparison between the AB and the ABC system, and more research would be beneficial to study in more detail the advantages and disadvantages with the two systems in different situations. These two years clearly showed that it is possible to implement a 100% grazed grass system with less than 1 kg concentrate/cow per day during more than 140 days per year. The flexible system described above, with a mobile milking unit and easy transfer between grazing areas is very advantageous in areas with fragmentation and where pasture utilization is economical.

In the second French region, Pays de la Loire, the conditions for pasture growth are not as favorable as in Brittany and farmers have to rely more on supplementary maize silage, not only during transition periods but also during the summer. An experimental farm at Derval (in this region) tested several cow traffic options and different herd management opportunities while grazing. During the last three years, the experiments were performed within the framework of the AUTOGRAASSMILK project. In 2013, maize silage was not used for 56 days. The Holstein cows in a 100% grazed grass diet produced 27.5 kg of milk with 2.8 kg of concentrates on average. The feeding cost was only one third of the winter ration. Each cow ingested up to 1.5 t of grazed grass per year. During the years 2014 and 2015, the grass growth in spring was not sufficient to feed cows on its own; it had to be supplemented by maize. While the supplementation of grazed grass with 5 to 8 kg DM maize silage/cow per day (depending on available grass cover) did not significantly affect dairy production levels, or milking frequency, the feeding cost was decreased while cows were grazing compared with the winter situation. These trials were led on a saturated milking robot (72 cows on average), with guided traffic and pre-selection process. This study indicated that grazing with an
AMS is possible as long as the farmer remains motivated, has a sufficient grazable area, and implements correct traffic options in relation to the saturation level of the robot. Beside this main experiment, a number of in-depth studies were also carried out to develop new technologies to register grazing time, to analyse the economic impact of grazing in AM systems and to measure and calculate intake of supplementary feeds and pasture during different parts of the season, thus providing the database to allow calculation of feed costs in these systems under varying conditions.

In Belgium, the data from the study comparing the effect of different levels of concentrates (performed in 2013) were compiled and further analysed during the second part of the project. The high concentrate group (HC) received on average 4.14 ± 0.03 kg/cow per day concentrates, while the low concentrate group (LC) received 2.14 ± 0.03 kg/cow concentrates. Milk yield was reduced over time for both groups as cows were at grazing. In May, the LC group produced more milk than the HC group (difference = 0.32 kg). Then, from June until the end of grazing, this trend changed. The greatest difference in milk production between groups was observed in June (difference = 1.96 kg). On average, cows in the HC group produced 1.07 kg milk/day more than cows in the LC group, over the season. This represented a milk response of 0.56 kg of milk per kg concentrate. Over the complete experimental period, cows in the HC group produced 131 kg more milk than cows in the LC group, while consuming 247 kg concentrates extra. Cows in the HC group had a shorter milking interval (MI) (by 35 min) than those in the LC group (P<0.001) and produced a higher milk yield per milking (MM) than LC cows (HC: 8.94 kg/milking ± 0.06 vs LC: 8.75 kg/milking ± 0.05 kg; P<0.05). Milk fat and protein concentrations were similar in both groups. Cows in the HC group returned to the robot more frequently, but this was also associated with an increased number of refusals (non-milking visits to the robot). This was more pronounced when grass availability and quality was reduced. The occurrence of returns to the robot and non-milking visits was consistent over time for the cows in the LC group. In conclusion, the trial showed that the response to concentrate offered to grazing cows in a mobile AM system was influenced by the grass quality and availability. The cow traffic to the robot was influenced by concentrates level with increased returns to the robot associated with high concentrate levels.

A further study was performed in Belgium to analyse the effect of mild heat stress on cow traffic and milk yield of grazing cows, within a mobile AM system. The study was performed at the Experimental Farm of University of Liège. A herd of about 50 dairy cows grazed on 24 ha of permanent pastures and were milked by a mobile AM system (Lely A3 next®). The cows grazed in a strip grazing system and two new pasture allocations per day were provided. Water was always available in a water trough (1000 litres) near the mobile unit. An individual bowl containing water was also accessible in some of the grazed paddocks. Transponders fixed on HR-tag neck collars (SCR, Israel) were used to identify the cows and to register several parameters, such as milk yield (kg/cow/day), number of milkings per day (/d), number of milking failures (robot failed to attach milking cluster), number of milking refusals (occurring if the delay between two visits is insufficient) and the amount of concentrate given. Temperature humidity indexes (THI) were calculated and were used to define, post hoc, heat stress (HS) periods. The daily THI during the HS periods were higher than 75. Each HS period was compared with a “normal period” (N), presenting the same number of cows, similar lactation number, days in milk, distance to come back to the robot and an equal access to water. One HS period of 5 days duration with a mean THI of 78.4 was observed in July. A second HS period of 6 days duration with a THI value of 77.3 was recorded in August. Parameters measured during HS periods were also measured in (N) periods of the same duration with mean THI <70. This allowed milk production, and robot parameters, such as milkings and refusals to the robot to be compared during HS and N periods. The events of milkings and refusals were significantly higher in HS periods compared to N periods in July (HS: 2.54 ± 0.11 vs N: 2.19 ± 0.08; 1.87 ± 0.20 vs 0.72 ± 0.16). This may be linked to water availability adjacent to the robot and thus confirms previous findings (Lessire et al., 2014). Milk production decreased from 21.8 ± 0.6 kg/cow per day during N periods to 18.9 ± 0.8 kg/cow per in HS periods. In August, milk yield was somewhat higher during HS periods. This may be due to lower ambient temperatures and reduced distance to walk for the cows, thus inducing less energy expenditure.

In Denmark, an on-farm experiment was performed in 2013 where a concentrate mixture with home grown concentrate ingredients (peas and barley) was compared with a commercial concentrate. The results showed that the cows had a lower milk yield and a lower milking frequency when fed the home grown concentrate. The conclusion of the experiment was that offering cows such home grown concentrate mixture (at the milking unit) was not economically competitive with the commercially purchased concentrate, at the current milk and concentrate prices. In the following two years (2014 and 2015), the feeding strategies of the monitor farms in Denmark were analyzed.
In Denmark, the feeding strategies of the monitor farms were analyzed during two seasons (2014 and 2015). The feeding data were gathered in cooperation with the extension services, who had instructed the farmers on how to record the feeding diet on the online monitoring and decision support software DMS (Dairy Management System). In both seasons there was large variation between the monitor farms in the percentage of fresh grass in the total diet of the cow, both over the grazing season only, and over the whole year. In 2015, fresh grass counted for 26.7%, 16.5%, 50.2% and 39.8 % of the diet in the grazing season for four monitor farms. There were also large differences in the self-sufficiency percentage of the monitor farms in DK, with these being recorded as 78.2%, 64.4%, 100% and 83.5%, respectively. Supplementary roughage feed was offered in the form of maize and grass silage, during the summer season. The concentrates were mainly used in the AM to attract the cows and the levels offered were 4.5 kg, 3.1 kg, 1.7 kg and 2.2 kg on the different monitor farms, respectively. The registrations showed no specific correlations between feeding regime and milk yield. However, there was a correlation (1.3-1.4) between milk yield and kg DM fed, thus implying that the similar milk yields could be obtained by grazing and by indoor feeding, and also by home produced roughage and concentrates, including proteins. The protein source was mainly supplied in the form of grass and Faba beans.

Task 1.3 The focus of the work within Task 1.3 of this WP 1 has been to establish “Optimum cow breed/type for an integrated grazing and AM production system”. This has been achieved during the second part of the project through an in-depth analysis of the response of different breeds to the treatments imposed in experiments performed within other tasks. This work was performed towards the end of the second period of the project to ensure that all relevant experiments were included in the analysis.

The Irish studies have focused on assessing the effect of breed on milk production and cow traffic, with the breeds (1) Holstein Friesian (HF), (2) Jersey x Friesian (JEx) and (3) Norwegian Red crosses (NRx). Irish analysis of the data indicated there was no effect of breed on the volume of milk produced/cow per visit or per day during summer and autumn in a pasture-based spring-calving herd, in an integrated cow grazing and AM production system. Cow traffic variables were similar for HF and JEx cows during the summer season, while HF cows spent less time waiting to milked per visit and per day than the JEx cows in the autumn period. The NRx cows spent less time waiting to be milked per visit than the JEx and HF cows during summer and autumn time, respectively. The NRx cows spent less time waiting to be milked per day than the JEx cows during the autumn. NRx cows had a shorter milking interval than the JEx cows during summertime and they had a shorter milking duration than both HF and JEx cows per visit, and JEx cows per day during the autumn period. These results suggest that NRx and HF cows were more efficient within the system than the JEx cows when taking cow traffic-ability into consideration. During the autumn period there was a significant interaction between concentrate level and breed for the variable milking duration per day. Concentrate and breed had a significant effect on feed intake and milking interval. Concentrate level significantly affected milk yield per day, whereas breed did not.

The Swedish experiments involved a comparison analysis of the suitability of pure bred Swedish Holstein (SH) and Swedish Red (SR) cows in an integrated AM and grazing system. Three experiments were conducted. In the first experiment, performance of the two cow breeds was similar in terms of milk production and cow traffic. However, a higher milk yield was recorded for the Swedish Holstein breed within the Swedish official control system, and this difference in production level has also been observed as a significant difference between breeds in the second experiment conducted as part of this study. However, the Swedish Red breed demonstrated a more active outdoor and grazing behaviour throughout the three experiments conducted in this study. Longer outdoor hours (significant in Experiment 1), higher number of outdoor visits (significant in Experiment 1; tendency in Experiment 2) and longer grazing hours (tendency in Experiment 1; significant in Experiment 3) were observed with the Swedish Red compared to the Swedish Holstein breed. However, potential benefits of the more active grazing behaviour, such as higher milk production have not been observed.

WORK PACKAGE 2: OPTIMISE THE INTEGRATION OF AM SYSTEMS WITH COW GRAZING USING NEW TECHNOLOGIES.

This work package was led by WLR and involved TEAGASC, LTO, AU, IDELE, SLU, ULg, CDL and the SME farm in Ireland. Optimum grazing management is a critical requirement to ensure the maintenance of an appropriate cow milking frequency in an integrated AM and cow grazing system. This work package addressed how technology could assist farmers in their pasture management. Various technologies that seek to secure animal health and welfare within an AM and grazing environment were also investigated, as were new AM technologies, such as the carousel and mobile robots. Ethical clearance was obtained by
the relevant RTDs for work conducted in this work package.

The deliverables associated with this WP have been completed and are as follows:
D 2.1: DST for precise management of cow grazing, tested and demonstrated
D 2.2: Practical tool to optimize grazing using detailed cow and grazing information
D 2.3: Guidelines for optimized operation of mobile milking units and automated carousel in grazing scenarios

TASK 2.1: PRECISION GRAZING MANAGEMENT FOR INTEGRATION WITH AM
OBJECTIVE: Develop a Decision Support Tool (DST) to assist grassland farmers with AM systems to improve the precision of their pasture management, thereby increasing the efficiency of their farming system.
MATERIALS AND METHODS: This task involved developing an information and communications technology (ICT) based tool with global positioning system (GPS) technology which will be capable of (i) mapping farms; (ii) capturing relevant grass measurement parameters (e.g. pre- and post-grazing herbage mass); and (iii) automatically transmitting data to a smart phone application and interacting with a data package, allowing the operator to be informed of where to place the fencing wire within the paddock in order to achieve an accurate grazing allocation.
RESULTS: The ICT based tool (also referred to as the Grasshopper) has been developed and described in the first periodic report. At the start of this reporting period, the Grasshopper was considered ready for further testing and validation. Further testing and validation was done during this reporting period and a Deliverable was produced (M24), “DST for precise management of cow grazing, tested and demonstrated”, which describes the results of Task 2.1. The Grasshopper was tested on research farms at Teagasc (Ireland), Institut de l’Elevage (France) and Wageningen UR Livestock Research (The Netherlands) under different conditions (sward types grass and grass clover, different sward heights, stages of sward growth and sward growth period e.g. tillering to finishing of flowering in spring, summer and autumn, different sward densities pre- and post-grazing). Furthermore, it was applied on the SME end user farm in Ireland. An operation manual of the Grasshopper was also developed. It was concluded that the Grasshopper measures grass height with high precision. It enables on-farm grass management to be improved and grass utilization to be enhanced.

TASK 2.2: EVALUATE TECHNOLOGIES TO SUPPORT THE INTEGRATION OF GRAZING AND AM SYSTEMS.
OBJECTIVE: (i) Evaluate technologies that support the integration of grazing with AM systems. Detailed information on these technologies and their operation have been generated, which will allow selection of the most appropriate technology(ies) to assist in motivating cows to visit the AM unit, and thus optimize the AM system.
MATERIALS AND METHODS: During the grazing period (May to September) robot and sensor data were collected on four research and two private farms in the Netherlands, Belgium, Denmark and France by WLR, UL, IDELE and AU, over three consecutive years. The accessibility to the pastures ranged from 7 to 24 hours per day. On farms with part-time grazing, cows received additional feed during their stay in the barn. The analysed data consisted of the data of the visits of the cows to the milking robot and the associated milk yields of all cows. In addition, data from activity and eating sensors were used. The changes in the rhythm and variation in the collected robot and sensor data were analysed.
RESULTS: Results are described in Deliverable 2.2. “Practical tool to optimize grazing using detailed cow and grazing information”. The number of cows per robot varied between 73 and 44. In general, as access to the pasture became extended, the number of milking per robot and thereby, also the milking frequency decreased. The farm with shortest pasture access time had the highest number of milkings per robot per day (160) and the highest milk production per cow per day (29.4 kg); the lowest number of milkings per robot per day (77) and lowest milk yield per cow per day (17.1 kg) were obtained on a farm with full-time grazing. At lower milking frequencies, the variation in the number of milkings throughout the day increased. On farms with 24 hour grazing three-hour periods with less than 3 milkings as well as three-hour periods with 20 milkings were observed. On the farm with the highest milking frequency and shortest pasture access time, the number of milkings per three-hour period throughout the day was frequently between 15 and 24. High milk yields were also achieved on a French farm in 2014 and 2015, despite a low milking frequency (2.03 and 2.09 respectively) and a long pasture access time of 21 hours. However, the recorded pasture times showed that cows in both 2014 and 2015 actually spent less than 25% of this access time in the pasture. In addition to factors such as the offered amount and quality of pasture and supplementary feed, milking frequency is an important indicator for milk production as well as the distribution of the interval lengths between milkings. Too
long intervals have a negative effect on milk yield, especially when the milk yield level is high. It was concluded that increasing access to pasture resulted in a lower milking frequency and lower milk production per cow. However, this effect may be influenced by the applied grazing strategy and daily management.

Cow eating time was recorded on three farms with two types of neck sensors. Grazing time was increased as grass intake (estimated) was increased. The total eating time was lower, if the proportion of grass in the diet was decreased. Cows at the Dutch farm with approximately 40% grass in the diet needed nearly six hours to consume the total feed. On Danish farms where two thirds of the diet was grass, time to consume the diet was more than seven hours. On a French farm with 100% grazing, cows required about nine hours for diet consumption. Despite 21 hours of access, cows on the French farm were actually only about five hours in the pasture and only less than half of this time was used for grazing. It was concluded that if the proportion of grass in the forage diet decreased, total eating time was lower. With 40%, 65% and 100% grass in the diet, cows needed almost 6 hours, 7 hours and 9 hours, respectively, to consume their diet.

Activity data of four farms were used in the development of oestrus detection models. These farms used three different sensor brands, IceTag, Nedap and Lely. The IceTag sensor was attached to a rear leg and recorded the number of steps of a cow per 15-minute periods. Total number of steps was on average 3,000/cow per day. The variation throughout the day was large, caused by pasture visits and grazing during the periods with pasture access. The Nedap sensor was attached to the neck and recorded intensive movements of the head per 15-minute periods. The total number of movements averaged little over 100/cow per day. The variation throughout the day was much smaller than with the IceTag sensor and was hardly affected by grazing. The highest activity was observed during the period when feed was made available in the barn. The lowest activity was measured in the early morning when most cows were lying down. The Lely sensor was also attached to the neck and registered activity per two-hour periods. It quantified all cow movements, e.g. walking, lying, standing, head movements and created a general activity index. This index was at a level of approximately 800/cow per day. The Lely sensor showed the smallest variation throughout the day. It was concluded that activity sensor brands use a variety of operating technologies and principles in which activity is measured and recorded. In addition, the sensors can be attached to various body parts.

Measured activity values therefore differ in level and variation throughout the day.

Heat detection models are usually based on the principle that a cow in oestrus exhibits an increased activity over a given period of time. In order to cope with the different characteristics of activity measurements, different approaches for oestrus detection models were used. For the default detection model with activity per day as the input parameter, sensitivity varied between 75% and 97.2 % and specificity was around 90% on all four farms. For alternative models, activities per two-hour periods were used as input parameters. In these models, sensitivity decreased and specificity increased as the activity data for an increasing number of consecutive two-hour periods were included. It was concluded that oestrus detection models could be developed with a sensitivity of more than 80% and a specificity of more than 96%. For further improving the performance, it is recommended to develop more sophisticated models, by making use of other available data such as cow calendar data (e.g. oestrus and pregnancy dates) and other automatically recorded data (e.g. eating time and milk yield).

**TASK 2.3: EVALUATE THE POTENTIAL USE OF ROBOTIC AM-CAROUSEL**

**OBJECTIVE:** (i) Evaluate the potential use of an automatic carousel (rotary) milking system, and provide guidelines for its optimum use. This milking system offers a potential option for use with large herds. This task focused on production and cow traffic in an AM carousel in SWEDEN during different phases of the pasture season, and under different conditions.

**MATERIALS AND METHODS AND RESULTS:** The effect of indoor silage feeding on pasture time was studied in an automatic milking rotary system with batch milking two times daily. The objective was to study how pasture time is influenced by offering only pasture (PP) or both grass silage and pasture (SP) in the barn during grazing hours, in a night-time grazing system, where cows could move freely between barn and pasture during pasturing hours. From June 9th until August 18th, treatments SP and PP were repeated three and two times, respectively, in two week periods using the second week for measurements. During each measurement week, ten animals were fitted with HOBO® loggers that estimated grazing time from the head position. Results were analysed in a mixed repeated measurement model using only cows (83) present during all periods. Results showed that animals on treatment PP spent approximately 8.5 hours on pasture with no difference between primi- and multi-parous cows. In contrast cows on treatment SP spent less time on pasture (p<0.001) and furthermore, time on pasture differed significantly between ages (p<0.001) in this group, with 4.7 h and 5.9 h for primi-parous and multiparous cows.
cows, respectively. Analysis of data on the grazing hours, obtained from the HOBO® loggers, showed a significant (p<0.001) difference between treatments with 3.8 and 2.2 hours of grazing on treatment PP and SP, respectively. Thus, no clear advantage, such as creating smoother cow traffic between barn and pasture could be seen for treatment SP. In summary the results showed that supplementary silage decreased outdoor time, gave a tendency for higher milk yield, gave no advantage with regard to cow traffic and is uneconomical when there is pasture available. All results with respect to robotic AM-carousel and grazing have been described in Deliverable 2.3 “Guidelines for optimized operation of mobile milking units and automated carousel with different amounts of supplements at different parts of the grazing season”.

**TASK 2.4: EVALUATE THE POTENTIAL USE OF MOBILE AM**

**OBJECTIVE:** (i) Evaluate the potential use of mobile AM systems and provide guidelines for their optimum use. The focus was on the use of mobile AM systems in remote areas and/or on fragmented farms, where grazing areas are difficult to access. A mobile AM system comprises a mobile milking robot, which can be moved to pastures during the grazing season.

**MATERIALS AND METHODS:** Guidelines on the combination of mobile AM and grazing were produced based on on-going experiments on the Trévarez site (IDELE, France, Pôle Herbivore des Chambres d’agriculture de Bretagne), the Sart Tilmant site (ULg, Belgium, University of Liège), and several years of practical experience on a farm in Denmark (AU). In all settings, the AM system could be moved to facilitate pasture grazing. The experimental site at Trévarez was equipped with a mobile robot (VMS Delaval on a Rolland chassis) in 2012 in order to test the compatibility of robotic milking on a group of dairy cows in organic farming, with the aim of optimising plots of land that were distant from the main farm site. A similar experiment started in 2010 in Belgium, on the University of Liège’s experimental site at Sart-Tilman, equipped with a Lely unit. The mobile robotic milking unit in Denmark was a SAC unit and has been in operation since 2009.

**RESULTS** Results with respect to the combination of mobile AM and grazing have been described in Deliverable 2.3. “Guidelines for optimized operation of mobile milking units and automated carousel with different amounts of supplements at different parts of the grazing season”. An overview of existing technical solutions is given, recommendations for new users are provided and the economic viability, environmental impact and regulatory requirements are discussed. It is concluded that the mobility of a robot is technically possible and adds value to pastures that are distant from the main farm. However, it is not easy to organise and requires a very early phase of planning and reflection by farmers. The motivations and objectives behind investment in a mobile automatic milking unit must be clear to all relevant stakeholders, i.e. the farmer, the suppliers, the advisors etc. The decision making must take into account milking and exploitation of grassland, and ensure that all other options have been considered (change of location of milking parlour, land re-organisation, etc.). All recommendations regarding the installation of a robot or grazing management are applicable. The experiments with mobile milking will continue beyond AUTOGRASSMILK and will further ensure optimisation of remote plots by herds of cows milked robotically.

**WORKPACKAGE 3: INCREASE THE SUSTAINABILITY OF AN INTEGRATED AM AND COW GRAZING MILK PRODUCTION SYSTEM**

The workpackage was led by the partner Aarhus University in Denmark (AU). Other participants included TEAGASC, IGA, WLR, ZLTO, AU, SEGES, IDELE, CNIEL, SDA, CDL, SME FARM DK.

The deliverables associated with this WP have been completed and are as follows:

- **D 3.1:** Protocol for registration of ‘Monitor Farms’, data capture and management of data
- **D 3.2:** A sustainability assessment tool for farmers to evaluate their own AM system

A stakeholder analysis was performed first to identify which stakeholders should be asked for their opinion on identifying sustainability indicators. Each project partner provided a list of stakeholders that seemed relevant to include in the participatory analysis (question list or interview). All answers were compiled and used to make a stakeholder analysis. Afterwards these identified stakeholders were contacted and interviewed, with the specific goal to identify sustainability issues and formulate indicators that could be quantified. Twenty-eight semi-structured interviews were conducted in the six countries of the project. Most interviews were done in France, Belgium and Denmark where it was possible to be physically present. Twice as many scientists were interviewed as farmers and advisors. Several meetings in the project group were used to discuss the procedures for quantifying indicators, and if the indicators registered should depend on the outcomes of the stakeholder analysis. TEAGASC and WUR coordinated an extension of an ongoing web based questionnaire on multi-purpose of
grass land use (Multisward), where some aspects of combining AMS with grazing were addressed. The questionnaire was analysed, annotating identification of stakeholders. It was decided that a registration of indicators should be started and the sustainability assessment would ascertain weighting of indicators for the different countries. Prioritized themes of sustainability per country were identified, and analysis on subthemes/indicators was performed. These were presented to a focus group in France and input was incorporated. The interviews among the stakeholders provided by the partner countries showed that economics was by far the dimension most cited as being most important (20 out of 23). All interviewed stakeholders defined sustainability as a combination between at least two of the dimensions economy, social and environment. The three dimensions were mentioned by 18 out of the 28 stakeholders, more often by scientists with (P=0.053). When applied to milk production, sustainability was also understood in terms of continuity of producing milk over the time (11/28). No differences among countries were found (P=0.828 and P=0.203 for mention of the three sustainability pillars and time continuity). A draft list of indicators which could be used for registering dairy farm data was discussed in the interviews, and the outcomes were used in the decision process for finalization of the registration schemes.

Results of the web based questionnaire showed that economics was the dimension with the most points (4.028) given by respondents, before environment (3.188) and social (2.784). These differences were significant (P=2.2×10−16). Farmers gave more points to economics than other stakeholders, followed by industries and advisors. Alternatively, farmers gave fewer points to the environment. French respondents gave fewer points than other countries to the economy and more points to the social dimension. People with a university background gave fewer points to the economic dimension and more points to the environment. Males gave more points to the economy and less to the environment. For dairy farmers, the presence of an AMS on the farm was not influencing the points given to economy and social. Dairy farmers with an AMS gave significantly fewer points to the environment.

The ‘Monitor Farms’ in all countries were selected by the SME associations in cooperation with their RTD partners, using criteria such as current effective integration of cow grazing and AM system, data capture ability, previous association with recording techniques, foreseen stability of the farm management, and farmers’ interest. It was decided not to try and find average farms, but select specific commercial farms covering the scope of what was going on in the countries dairy farms using AM and grazing. This resulted in DK (6), IRE (7), F (6), NL (4), B (4), S (5), and LUX (4) farms. Luxemburg joined the project voluntarily, and the project Management Committee (PMC) agreed on including their registrations. Ireland only registered for the year 2014. Registration schemes based on the EU-Dairyman protocol and supplemented with specific indicators focused on issues concerning AM and grazing. Measurement systems for data collection on dedicated sustainability indicators such as working hours, grass height, or grazing time were put in place on the farms. Economic data was collected from the accounts of the ‘Monitor Farms’ using the appropriate data capture system for specific countries. The SME partner farm DK was used for feed-back and for in depths analysis of technological decision support.

Data of 36 AMS farms practicing grazing was collected for the production years 2013 and 2014. To secure direct contact with the monitor farms, and use the collected information for benchmarking and discussion, several countries organized yearly meetings as “field days”, “farmer study groups”, or as “summer meetings”. At national conferences, researchers from the AUTOGRASSMILK project have used registrations from monitor farms as examples. Data from the monitor farms were used in WP 1 to study best practice on feeding strategies, and in WP 2 to analyze the implementation of sensors, as technical decision support for grazing and health registration. The extensive data collected during the three year project is in principle owned by the SME Associations in the respective participating countries. It was decided at the PMC meeting in December 2015, held in Dublin, that the SME Associations are willing to provide the foreground data for scientific analysis beyond the objectives of this project. It was decided that all information should be kept anonymous. All SME Associations involved have been asked to sign a declaration which makes the data available. AU will administer this.

Parallel to the data collection a wide range of existing sustainability assessment tools were studied (De Olde et al.,2016) including the Dairyman Sustainability Index (DSI) (Elsaesser et al., 2013; Elsaesser et al., 2015), RISE (Häni et al., 2003) and SAFA (FAO, 2013). The DSI tool is based on the gathering of data by farm registration schemes which were made available by the Dairyman team. In these indicator-based sustainability assessment tools, the sustainability performance of a farm is generally evaluated on economic, environmental, and social themes. In SAFA, a fourth dimension of sustainability is added: governance, to discuss more institutional and managerial themes. This dimension was added as it was valued of importance.
for the sustainability of an enterprise.

To assess these four dimensions of sustainability a procedure was developed to define the relative importance of themes within the dimensions. During a session of the PMC all partners involved were asked to define which themes they found important for the assessment of the sustainability performance of AM dairy farms within the economic, environmental, social and governance dimensions. This resulted in lists of themes which were grouped, and resulted in a final list of 25 themes. All partners were asked to distribute 100 points over the themes in each dimension to determine the weight within each dimension (Table 1, Appendix 1). To assess the performance on each theme, 50 indicators related to these themes were identified from the registration schemes used in the AUTOGRASSMILK project to assess the monitor farms. During consortia meetings the list of indicators was discussed and experts were consulted to discuss the calculation of economic indicators. Moreover, an existing French tool (CAP2er) was used for the calculation of biodiversity and GHG emissions.

What is considered sustainable farm performance can vary in each context. Therefore, each participating country was asked to define its own reference values to be used in the assessment tool. To gather the country specific reference values, the RTD partners in each country got scientific feedback from the relevant specialists. The starting point for gathering reference values was to gather the values of the worst 25% quantile and the best 25% quantile of all AM farms with grazing in their country. Afterwards these quantile reference values were evaluated for their absolute quality, alignment with legally agreed values and scientific literature. The outcome for these country specific reference values are shown in Table 2, Appendix 1. For these 26 indicators, the zero (=bad) values for the countries differed especially (> 10% for more than two countries) for N balance, P efficiency, fuel costs per ha, farm net income per dairy cow, variable costs per dairy cow, dependency on subsidies, invested capital per hour of labour, days outside grazing, health care costs, and SCC. For the 100 values (=good) there were different perceptions (> 10% for more than two countries) on almost all indicators. The reference values of the other 24 indicators were fixed as there is a general understanding on what is considered good or bad for sustainability (e.g. having a successor or not, or having a good or poor relationship with neighbors).

In Ireland a state of the art carbon footprint analysis was made on the monitor farms selected. Greenhouse gas emissions from dairy farms were calculated using the LCA model of O’Brien et al. (2014) which was certified by the Carbon Trust according to the British standard (BSI, 2011; PAS 2050). In addition, in Ireland, labour data was generated based on an on-farm study where the seven monitor farms participated in a year-long labour study. Table 3 (Appendix 1) shows some basic specifications per country when averaging the monitor farms (n = amount of monitor farms with complete registrations for at least one year).

The average country values were deducted from the registrations of the monitor farms. The monitor farms were not representative for the country, because the project could not provide means for the amount of farms needed for representative monitoring. Table 3 shows that the monitor farms in Belgium, the Netherlands, and Sweden (in particularly) are larger than the average for those countries and milk yield in Belgium and the Netherlands is also higher. In Denmark 4 of the 6 farms were organic, which reflects the somewhat lower milk yield than the country’s average. More details on the monitor farms can be found on the web page www.autograssmilk.eu.

Evaluation of the monitor farms sustainability was performed using reference values per country. In this way the sustainability per country could be evaluated relative to what experts in the countries had defined as their scale. In the evaluation of the sustainability a linear scale (0-100) was used to calculate the scores for the respective dimensions.

Economic dimension: For the 2013 (Figure 1, Appendix 1) data it is clear that the economic dimension is a challenge. Even though most countries had accepted a negative income occasionally in their reference values, the 2013 economy looked poor. Ireland could not deliver all indicator values for the economic dimension and therefore the total evaluation is not included. However when the scores for some indicators were examined, Ireland was the only country scoring positive Net Farm Income. Also in 2014 the economy scores were poor, expressing the present crisis within the European dairy sector.

Environmental dimension: The environmental average scores (Figure 1, Appendix 1) on the themes within the environmental dimension were reasonable. To evaluate this result the separate indicators measuring environmental themes were examined. It showed that energy consumption/ha and nutrient balance negatively influenced the results in Belgium and Luxembourg. Biodiversity scored low in all countries. The countries perceived nitrogen surplus differently (Table 2, Appendix 1), the actual levels of Nitrogen surplus varied from around 60 kgN/ha in Sweden and Denmark (> 50% organic farms) to the Netherlands (160 kgN/ha), Belgium (194 kgN/ha), France (158 kgN/ha) and Ireland (186 kgN/ha).

In Ireland, where AM is new, the monitor farms were used to examine a detailed Carbon footprint (CF). The mean CF of milk
was 1.33 kg of CO2-eq/kg of FPCM for the AMS farms and ranged from 0.97-1.88 kg of CO2-eq/kg of FPCM. All farm footprints were within the range of recent estimates for developed nations e.g. 0.6-2.8 kg of CO2-eq/kg of milk for UK and USA farms (DairyCo 2012; Thoma et al. 2013) and within the lower range of international evaluations (e.g. Opio et al. 2013) and was similar to previous Irish estimates (Yan et al. 2013). There was no major difference in where the emissions originated from, when compared.

Social dimension: The scores on themes within the social dimension (Figure 1, Appendix 1) were similar to the environmental dimension. The social dimension included the themes animal welfare, working hours, work quality, image and participation, farm continuity, work-life balance, and product quality. The scores on working hours were low in most countries due to a relatively high number of hours worked per week and the self-evaluation on the indicator overworked. Nevertheless, the total evaluation on the social dimension scores was positive, although the themes scored quite differently per country (Figure 2, Appendix 1). For example, the scores on animal welfare varied widely between countries, the absolute scores of some animal welfare indicators also showed differences.

In Ireland it was decided to make a detailed comparison of labour use on Irish automatic milking- and conventional dairy farms, as this still is a big issue there. Labour data was generated based on an on-farm study where the seven Irish monitor farms participated in a year-long labour study. In addition the same was done for 10 conventional Irish dairy farms. Total dairy labour input was 15.8 hours/cow per year on automatic milking farms. On average conventional milking farmers spent 3 hours/day at the process of milking. As AMS does not require the farmer to be present at milking time, the milking process only consumed 0.7 hours/day for the AM farmers (range 0.2-1.1 hours/day). This saving in labour from the milking process, was partially counteracted by significantly (p<0.001) more time being spent at grass allocation with an AM system. AM farmers spent on average 0.4 hours/day ensuring their cows were allocated the correct amount of grass in each grazing area. However, as the conventional milking farmers were not dependent on the allocation of grass for optimum cow traffic, they only spent 0.12 hours/day attending to grass allocations. Time at grass allocation was highest for the conventional milking farms in spring (0.28) when there may have been a greater focus on grass allocation to increase grass utilization in poorer weather conditions, although this was still lower than the time spent by AM farmer. Despite labour being reduced by 8.7 hours/cow/day, daily end of work times were the same for each milking system, at 18:32 (hh:mm). However, daily start time were significantly different (p<0.05) with AM farms starting work almost one hour later than conventional milking farms, at 7:55 and 7:05 (hh:mm), respectively.

Governance dimension: The governance scores were high for all countries. Farmers were especially positive when asked if they were satisfied on their relations with the community and society, and their relation to other farmer colleagues. Weaknesses were observed in farmers’ corporate social responsibility and diversification and openness. Here France, the Netherlands and Belgium score lowest.

Sustainability assessment tool for farmers. Having experienced the value of sustainability assessment using indicator based registrations, the framework was transformed into an Excel based tool. The tool requires that the farmer fills in the specific registrations used in the computing of the sustainability scores are in the tool. The tool is available on the website (Deliverable 3.2).

WORK PACKAGE 4. ECONOMIC ASSESSMENT OF INTEGRATED GRAZING AND AM TECHNOLOGIES. This work package was led by TEAGASC and also included WLR, LTO, AU, CNIEL, SDA, Ulg and CDL. The work package comprised four tasks.

The deliverables associated with this WP have been completed and are as follows:
D 4.1: Report on the financial impact of different levels of grazing for Denmark, the Netherlands and France over a number of years
D 4.2: Web based decision support tool for NW Europe on economics of AM and grazing

Task 4.1 ECONOMIC IMPACT OF GRAZING DAIRY COWS ON FARMS EQUIPPED WITH AN AUTOMATIC MILKING SYSTEM (AMS)

OBJECTIVE: (i) Assess the economic implications of integrating grazing with AM systems and specifically: to conduct an economic appraisal of dairy farms deploying AM with and without integrated grazing, on farms in France, the Netherlands, and Denmark.

METHODS: The comparisons have been completed on a: per litre of milk produced, per hectare of land farmed, and per farm
basis. The accounting databases were different for the three countries involved in this task and are specified below:

**Denmark:** The Danish economic data was available on the Knowledge Centre’s (SEGES.dk) database of all dairy farms in DK, but it did not indicate if Danish farms grazed or not. The information as to whether a farm grazed or not in the accountancy year 2012 was obtained by asking the milk quality assessor from the different regions to identify farms with grazing. Afterwards these farms and their advisors were contacted by telephone. In all, 14 dairy farms with grazing and 67 parallel dairy farms without grazing were identified and used in the analysis. Economic parameters were computed using the dimensions MJ NEL (Net Energy Lactation) for feed intake and kg of ECM (energy corrected milk (Sjaunja et al., 1990)).

**France:** Using the Inosys French bovine dairy farms reference network, 37 farms equipped with an AMS among the 630 farms were identified. The economic and technical performances of these farms are stored annually in software named “Diapason”. This database was used to analyse and assess the strengths and weaknesses brought by the combination “AMS and grazing” in dairy farms. This analysis was carried out in the following way: (i) Within the sample of AMS farms, the economic results of the farms according to the share of grazed grass in the cows’ diet were compared; (ii) To limit the impact of a single year effect, data of three consecutive years were used: 2010, 2011 and 2012. As the information on grazed grass in the cow’s diet does not directly exist in the Diapason database, it was estimated.

**The Netherlands:** In the Netherlands, data from approximately 10% of all Dutch commercial dairy farms in 2011 were used to assess economics associated with grazing. Six different data sets of accounting firms and advisors were explored for this purpose (Countus, DLV, DMS, Flynnth, LEI and PPP-Agro Advies). Data envelopment analysis (DEA) (Cooper et al., 2000; Steeneveld et al., 2012) was used on the data collected by accounting firms and advisors. DEA allows the efficiency of the use of resources (land available, feed imported, material imported, herd, capital, labour) to be determined. DEA studies the ability of firms to use inputs (e.g. capital and labour) to produce outputs (e.g. revenues). DEA is a nonparametric method of calculating the efficiency of individual decision-making units (DMU). DEA compares the levels of inputs and outputs for a given DMU against all other DMUs in the dataset to determine which DMUs are producing at efficient levels relative to the entire group. To specifically focus on the effect of the combination of grazing and automatic milking, the largest dataset (n=1109 in 2011) was used, since these data provided the most reliable results (Hogeveen et al., 2013). In this dataset, 81% of the farms practiced grazing and 17% used automated milking. The dataset contained financial data (revenues, costs, depreciation, etc.), technical data (land area, number of animals, soil type, milk yield, milk quality, etc.) and social data (successor, age, etc.). The technical details of DEA have been described by Hogeveen et al. (2013).

**RESULTS:** Economic analysis of AMS farms with and without grazing.

**DENMARK:** In Denmark, 14 dairy farms with automatic milking and grazing were selected. These farms were characterized and a parallel set of 67 farms without grazing were identified and analysed. Only farms with a business unit analysis (split costs and revenues for livestock and crops) in their annual report for their milk production from the accountancy bureau were chosen. The two groups were tested for normal distribution and critical values for distinction of differences were computed. The group without grazing (n = 67) had an average herd size of 140 cows, while the group with grazing (n=14) had an average herd size of 123 cows. No significant differences in production price per kg ECM, Feed costs per kg ECM, Yield in kg ECM, Veterinary and medicine costs per cow and Purchased feed costs per cow per year were found. However, the graph (Figure3, Appendix 1) of euro per cow spent on purchased feed showed an interesting trend. Especially among the group of farms that spent relatively little money on purchased feed, the farms with grazing used consistently less money per cow on purchased feed than the farms without grazing. The costs of different feed entities of the farms were analysed. Farms that grazed their cows had lower costs associated with purchased proteins as a separate feed entity, compared to farms that didn’t graze. However, it is not known exactly how much protein the mixed concentrates contained. The price of roughage was very important as it was the largest entity of the feed in the diet. This applied for both grazing and zero grazing herds. In the top 5 herds with grazing cows, 50% of the diet consisted of roughage, indicating that roughage was cheaper than concentrates.

**FRANCE:** Practicing grazing resulted in a shorter time spent inside the shed by the cows and thus a lower time available for milking at the robot; which is the key challenge with maximizing the use of automatic milking boxes when practicing grazing. However, in the French study the number of cows per AMS box and the milk produced per box did not seem to differ from one group to another (Table 4, Appendix 1). The milk yields did not appear to be different from one group to another though the “intermediate grazing” group reached slightly higher yields (Table 5, Appendix 1). Grazing is linked with a lower use of concentrates for dairy cows (per cow and per l milk). Practicing grazing resulted in lower feeding costs, associated to lower...
costs of inputs both for animals and forage areas (Table 6, Appendix 1). The lower saturation level of the AMS box led to an extra cost of “buildings and equipment” with grazing. The labour costs were directly affected by the productivity of the labour force of the dairy unit of the farm. The production cost before repaying the labour force of the farmer was lower in the “intermediate” and “grazing” groups. The income of the dairy unit was also greater for the “grazing” groups in relation to higher grants. This led to “the more grazing, the higher profits” either per working unit or per 1,000 l milk produced. This study confirmed that on the AMS farms, it is interesting to keep as much grazing as possible for dairy cows, as this results in a lower feeding cost. However, it seems necessary to have fewer cows per AMS box or to change the grassland management of the grazing herds to optimize the management of the grazing periods when the cows are outside grazing and the robot spends more time idle.

THE NETHERLANDS: When analysing the financial records of commercial dairy farms with and without AMS (Hogeveen et al., 2013), large differences were found between farms regarding efficiency and gross operating profit (gross operating profit being the difference between revenue and the cost of the farm before interest and taxes). On average, grazing resulted in more efficient operational management and a higher gross operating profit. However, these positive results declined with increasing farm size. In 2011 the transition point was a farm size of 85- 90 dairy cows. In 2011, the majority of dairy farms in the Netherlands did not yet have the option of receiving a grazing premium. Today, however, most dairy companies have implemented the grazing premium. The current grazing premium would have made the transition point increase to a farm size of approximately 130-140 cows. Unfortunately, the actual grass intake on the commercial dairy farms was unknown. Therefore, it was not possible to relate the grass intake to the farm income. The category ‘grazing farms’ included both farms with very low grass intake and farms with full grazing. If grazing was combined with automatic milking, much of the efficiency and financial advantage of grazing disappeared. In the dataset, the gross operating profit of grazing was on average € 21,628 higher per farm (P=0.001). Automatic milking reduced this effect by € 16,151 (P=0.04). So the positive effect of grazing was still present in situations of automatic milking, but was much smaller. This may be associated with the abovementioned effect of the grass intake. For the commercial dairy farms in the dataset, the fresh grass intake for the dairy farms with grazing was not known. It seems plausible that in general the fresh grass intake of farms with automated milking and grazing was lower than the fresh grass intake of farms without automated milking and grazing since the land area that can be grazed is usually smaller in the Netherlands for farms with automated milking. Farms with automated milking can only use grasslands near the buildings for grazing, while other farms can also use grassland somewhat further away. A further study was conducted in 2014 and 2015 to test this hypothesis. The dataset was combined with a questionnaire asking farmers about the fresh grass intake on their farms and using multiple years of data. Multiple linear regression showed that fresh grass intake was related not only to technical factors like the land area available for grazing, but also to social factors related to the mind-set of the farmer with respect to grazing.

Difficulties in comparing grazing and non-grazing farms: It is difficult to do a more detailed comparison of grazing and non-grazing and difficult to draw final conclusions because the results of the three countries differ a lot in terms of production systems, management, traditions and location (Denmark, France, the Netherlands). In general, introduction of grazing into feeding systems mainly based on maize silage leads to an interesting decrease in the feeding cost, in particular for the concentrate component. In contrast it leads to higher equipment costs in situations of farms with AMS, possibly because of a lower average saturation level of the AMS boxes on these farms (e.g. for France 60 cows per box in the “grazing group” versus 66 cows per box in the “non-grazing” group).

Other considerations: Farmers should take sufficient time when choosing a new milking system (parlour, AMS, mobile AMS, AMR) or when changing milking equipment. Precise estimation of the future impact of AMS technology on the whole production system, including a decrease in grazing and an increase in the requirements in stored forages, higher maintenance and equipment costs, as also extra management skills to cope with the challenges of cow traffic and changing feeding plans for winter and summer, should be analysed. The decision seems more strategic on the farms with a high proportion of grazed grass in the dairy cow’s diet, which means sufficient land adjacent to the milking unit. Once the decision is made and the robot is working, it remains interesting from an economic point of view to graze the cows; but this implies that the AMS box is not fully saturated.

TASK 4.2: ECONOMIC COMPARISON OF AUTOMATIC MILKING AND CONVENTIONAL MILKING SYSTEMS IN AN IRISH PASTURE BASED SYSTEM.
OBJECTIVE: (i) Assess the interaction between capital investment, labour requirements and running costs for integrated grazing and AM technologies.

MATERIAL AND METHODS: The Moorepark Dairy Systems Model (Shalloo et al., 2004) provided the mechanism by which the milk production, milking system and labour data could be analysed economically. This is a stochastic budgetary simulation model of a dairy production system. The model integrates animal inventory and evaluation, milk supply, feed requirement, land and labour utilization and economic analysis.

Scenario Description
The six milking technology investment scenarios were:

AMS Single Unit (AMS-SU). One AMS unit milking 70 cows twice daily.
12 Unit Medium Specification (MS) Conventional Milking (CM) Parlour (12MS). 12 unit herringbone milking parlour, milking 70 cows twice daily with MS technology, such as batch feeders in the milking parlour and swing-over arms.
12 Unit High Specification (HS) CM Parlour (12HS). 12 unit herringbone milking parlour milking 70 cows twice daily with individual electronic cow feeders, swing-over arms, automatic cluster removers, electronic milk meters, automatic identification, automatic drafting, automatic washer, automatic cluster cleaning between individual cow milkings and an electronic dump line.
AMS Double Unit (AMS-DU). Two AMS units milking 140 cows twice daily.
20 Unit MS CM Parlour (20MS). 20 unit herringbone milking parlour, milking 140 cows with MS technology (see 12MS for technology description).
20 Unit HS CM Parlour (20HS). 20 unit herringbone milking parlour, milking 140 cows twice daily with high specification technology (see 12HS for description).

Model Inputs: On farm labour data was recorded on AM and CM farms from March 2014 to February 2015, for three consecutive days each month. The study involved the recording of labour input data for various defined farm duties across a range of different task categories. Milking machine purchase prices and service costs for AM and CM were obtained from the list prices of the manufacturers and suppliers of each system. Electricity consumption was recorded using a wireless monitoring system which calculated cumulative energy used (kWh) at 15 minute intervals for each on farm electricity consuming process.

Model Assumptions: Biological model assumptions included; farm sizes of 28ha and 56 ha for medium farm (MF) and large farm (LF), respectively, and a stocking density of 2.5 cows/ha was applied to each farm simulation. Annual milk production of 5,000l/cow, concentrate supplementation input of 350kg/cow, grass growth of 13 tonnes DM/ha and replacement rate of 18% were assumed across both farm sizes and all 3 milking systems. These assumptions are based on historical Irish data. Labour was valued at €12.50/hour while an opportunity cost of land was included at €445/ha. Milking equipment and farm infrastructure were depreciated over a 10 and 20 year period, respectively. The investments were financed over 10 years at interest rate of 5%.

RESULTS: Total dairy labour input was significantly less (p<0.05) on AM compared to CM farms, with AM farmers working 15.8 hours/cow per year and CM farmers working 25 hours/cow per year. When labour rates of €12.50/hour were applied to the data, overall reduction in labour resulted in a simulated lower labour cost on the AMS-SU and AMS-DU farms at €14,078 and €28,155, respectively, compared to CM farm costs of €22,179 and €44,357 for the two herd size categories. As a percentage of total costs of production for each system, labour on AMS-SU and AMS-DU farms accounted for 11.2% and 12.8% of total costs, respectively, while labour on conventional milking farms with 12MS, 12HS, 20MS and 20HS accounted for 18.8%, 17.3%, 21.3% and 20.2% of total costs, respectively.

The highest total discounted farm net profit, at both farm sizes, was achieved by the 12MS and 20 MS milking systems at €151,480 and €559,713, respectively. This was 74% and 25% greater than AMS-SU and AMS-DU at €86,868 and €449,777, respectively. While AMS achieved intermediate profitability at MF size, it was marginally (€1,949) less profitable than 20HS at the LF size. This was due to AMS-DU requiring the largest capital investment at this farm size. Trends for discounted net cash flow were similar to those of profitability. The return on additional investment for AMS and HS technologies relative to the base (MS) were negative due to the higher capital costs and lower returns associated with these technologies.

TASK 4.3: ECONOMIC OPTIMISATION OF AUTOMATIC MILKING THROUGH INCREASING COW NUMBERS PER ROBOTIC UNIT.
OBJECTIVE: (i) Optimise the impact of a variety of innovative feeding and grazing technologies on dairy farm efficiency.

MATERIAL AND METHODS: The Moorepark Dairy Systems Model (Shalloo et al., 2004) provided the mechanism by which the milk production, milking system and labour data could be analysed economically. This is a stochastic budgetary simulation model of a dairy production system. The model integrates animal inventory and evaluation, milk supply, feed requirement, land and labour utilization and economic analysis. The effect of cow numbers on AMS and individual animal performance was generated based on a two year long study carried out in the Teagasc/Dairygold research farm in Kilworth Co. Cork over 2014 and 2015. Two sets of cow numbers (50 and 70) were put on experiment across a two year period with the same management operated across year. Treatment 1 (50 cows) operated in 2014 and treatment 2 (70 cows) operated in year 2 (2015). While not ideal in relation to experimental design, it is the only feasible way of carrying out this type of experiment where there is only access to one single robotic unit. The experimental results showed a 3.4% lower milk yield (4,876kg vs 5,047kg) for the 70 cow treatment when compared to the 50 cow treatment where there was a difference of milking frequency of 4.9% (1.57 vs 1.65) milking’s per day.

Scenario Description: The two scenarios investigated on a single AMS for a full calendar year were 50 and 70 cows. The two scenarios were simulated over a ten year period with annual profit generated for the farm as well as a total discounted net farm profit over the ten years of the study with a discount rate of 2.5% included in the analysis.

The cow number scenarios investigated were:

AMS Single Unit (AMS-SU). One AMS unit milking 50 cows
AMS Single Unit (AMS-SU). One AMS unit milking 70 cows

Model Inputs: On farm labour data was included as per Shortall et al., (2015) where each cow that was being milked in the AMS unit required 15.8 hours per cow per year. Milking machine purchase prices and service costs for AM were obtained from the list prices of the manufacturers and suppliers of each system. Electricity consumption was recorded using a wireless monitoring system which calculated cumulative energy used (kWh) at 15 minute intervals for each on farm electricity consuming process. It was assumed that a certain proportion of the energy associated with the AMS was fixed (i.e. didn’t change with cow numbers or milk output due to machine washing etc) while the rest of the electricity requirement altered based on the milking’s completed.

Model Assumptions: Biological model assumptions included; farm sizes of 28ha and a stocking density of 2.5 cows/ha was applied to each farm simulation. Annual milk production of 5,047kg/cow and 4,876kg/cow for the 50 and 70 cow treatments, respectively. Concentrate supplementation input of 350kg/cow, grass growth of 13 tonnes DM/ha and replacement rate of 18% were assumed across herd sizes. These assumptions were based on historical Irish national data as well as from experimental results. Labour was valued at €12.50/hour while an opportunity cost of land was included at €445/ha. Milking equipment and farm infrastructure were depreciated over a 10 and 20 year period, respectively. The investments were financed over a ten year period at an interest rate of 5%. Milk price was included in the model at 29.5cpl. The 50 cow herd required less land than the 70 cow herd with the additional land assumed to be used as an alternative enterprise with the opportunity cost assumptions based on the land being used for an alternative enterprise (e.g.beef etc) with an opportunity cost of €445/ha as identified above.

RESULTS: Annual profit: Annual profitability was consistently higher where cows were milked less frequently (more cows in the herd). As all costs were included in the analysis, net profit was consistently low irrespective of the milking frequency/herd size evaluated. On average net profit was five times higher (€12,727 vs €2,143) in the larger herd size when compared to the smaller herd size even though milking frequency and milk yield was lower. The difference in profit ranged from €9,792 to €11,331 between the two herd sizes and milking frequencies but was consistently significantly higher with the larger herd size.

Discounted: In order to include the time value of money from different investments in a business, total discounted net farm profit was included as a metric in the analysis. Over the ten years when the two different herd sizes were compared taking into account the time value of money, there was a very big difference in total discounted net farm profit. Over the ten years evaluated the large herd size generated 6.4 times more net real profit for the business (€111,834 vs €17,451).

TASK 4.4: DEVELOPMENT OF A DECISION SUPPORT TOOL (DST) TO QUANTIFY THE INTERACTION OF FEED SYSTEMS AND AMS SYSTEMS

OBJECTIVE: (i) Develop a decision support tool to assist dairy farmers to economically optimize their production system
integrating grazing and AM for different regions in the EU

MATERIALS AND METHODS: For the development of a decision support tool (DST) for task 4.4 every participating country had a representative. In skype-meetings and a physical meeting at the end of April 2015 the group decided what results of AUTOGRASSMILK (and other projects) would be included in the DST and what interactive computer programs could be developed. In this selection the main goal, namely to support farmers’ decisions, was considered. In the period between April and October 2015 research results were processed into items with information that was expected to be useful for practical farmers. In addition two web-based interactive computer programs were developed. At the end of October 2015 a meeting took place in which the content of the items in the DST and the two computer programs were discussed with the representatives. The items were included in a web-based document, including links to research information and to the computer programs. The final product was discussed with a larger group of project members in December 2015.

RESULTS: A document/decision support tool has been designed for farmers that have a combined AM and grazing system, and want to obtain information on this combination. This document combines research and practical knowledge accumulated in the project. A number of topics concerning grazing and AM systems have been accumulated. By clicking on a topic, the user can navigate into the document to the location where this topic is described. From a specific topic the user can navigate back to the list of topics and click on an alternative topic. The user can also scroll through the document from top to bottom and study all available information. In a number of topics, links to external tools or documents are included. They are in most cases situated on the website www.autograssmilk.dk. Some information is generic, meaning that it is valid for all countries but some information is country specific. Included topics: Factors influencing the performance of an AM system; Milk production per cow with an AM system; Number of cows per AM system when integrated with grazing; Effect of integrating grazing and AM system; AM system parameters influencing milking frequency and milking interval; Cow traffic and use of a grazing gate; Distance from pasture to AM system; Availability of water; Grazing management; Costs and Labour for AM system.

Additionally, two web-based programs are developed and linked into the DST. They are:

1) GrazingWise: http://webapplicaties.wur.nl/software/grazingwise

The goal of GrazingWise is to estimate quickly the consequences for labour requirement, economy and manure legislation of alternative grazing systems, either with or without an AM system. With GrazingWise different grazing systems can be compared. It can evaluate rotational systems: day and night grazing, day grazing, grazing during afternoon and evening; indoor systems: permanently indoors with fresh grass, permanently indoors with conserved roughages; and continuous grazing. The amount of indoor feeding with roughages combined with grazing can be varied in a number of situations.

GrazingWise is developed by the Dutch partner. All participating countries had the opportunity to test GrazingWise.

2) Beteskalle: www.hir.se/dst/self.exe

The goal of Beteskalle was to estimate how much grass is available per cow, depending on number of cows, area of grassland and production per ha. The remaining need for feed was filled in with supplementary feeding. With the results, the profit that can be achieved from grazing was also estimated. Beteskalle is developed by the Swedish partner in cooperation with H. Kohnen from Luxemburg who worked parallel with the project Autograssmilk on a project for Luxemburg. All participating countries had the opportunity to test Beteskalle.

WORK PACKAGE 5. DISSEMINATION. This work package was led by VFL The overall objective was to make research results and accumulated knowledge of all partners in the project applicable and accessible to the owners, i.e. the SME-AGs, their members, the wider group of farmers, extension personnel, the scientific community and policymakers.

The deliverables associated with this WP have been completed and are as follows:

D 5.1: Preparation and circulation of a project press release; establishment and launch of the project website; and on-going updating of the project website
D 5.2: Interim dissemination plan
D 5.3: Video presentations of the project results
D 5.4: Final dissemination plan

TASK 5.1: DEVELOPMENT AND MANAGEMENT OF PROJECT WEBSITE

OBJECTIVE: To maintain the project website.

PROGRESS: The website was designed and developed, and was launched in March 2013. The website has been dynamic and
has been changed as required. A range of information relating to cow grazing has been published (in the different national languages) on the website in autumn 2013. National events have been published on the website’s Events list and this is regularly updated. Presentations delivered by project RTD and SME-Ag representatives at conferences, seminars and workshops have also been uploaded. The publications and presentations are listed under the relevant work packages. The regular updating of the website has been an important on-going task.

**TASK 5.2: MONITOR FARMS’ AND SME END USER FARMS**

**OBJECTIVE:** Disseminate information from and through the monitor and SME end-user farms.

**PROGRESS:** Ireland: A number of farmer discussion groups, student groups and international groups have visited the AM unit at Moorepark. In total, approximately 230 visitors have visited the AM unit in 2013. A number of farmer discussion groups have visited the AM unit at Teagasc, Moorepark in 2014 and 2015. In total 455 and in 291 farmer and other groups visited the AM unit at Teagasc, Moorepark in 2014 and 2015, respectively. A farm walk attended by 140 farmers was held by the Irish SME farm partner in October, 2015.

In Sweden, a farmer conference was held in Sweden in May, 2014 (Betesda Lövsta). A similar farmer conference was held in November, 2014 (Satsa når det är svårt läge? Bygga och trimma för en hållbar mjölkproduktion).

In Denmark, a farmer conference (attendance of 70) was held by VFL (Afgræsning - sæt koen i arbejde) in February, 2015. A similar farmer conference was organized in (Teknologi til styring af afgræsning) in June, 2015 and in September, 2015 with 35 farmers attending.

Belgium: Farmer and student groups have visited the AUTOGRASSMILK trial in Sart Tilman (University of Liège). The following visits have taken place during 2013: Comice de Durbuy (5th July) - attended by 35 farmers; AREDB Herve-Fléron-Visé (25th September) - attended by 12 farmers; Ceta Waimes (30th September) - attended by 8 farmers; Lycée Agricole Ettelbuck Luxemburg (10th October) – attended by 10 students; German organic farmers’ group (16th October) - attended by 12 farmers. In Belgium, farmer information meetings/conferences on AM and grazing were held in July, 2014 (Foire de Libramont), in April, 2015 (30e anniversaire d’Agra-Ost. La gestion des prairies), June, 2015 (Foire de Libramont), September, 2015 (Results Experimental- and Pilot farms), December, 2015.

In France, a farmer meeting was held in September, 2015 (Technical days in Trevarez on robotic milking and grazing).

In the Netherlands, meetings were held in October 2015, (Symposium Robot & Weiden, farmer meeting), in November, 2015 (Landelijke Onderwijsdag ‘Gezonde veehouderij’, agricultural teachers) and in December, 2015 (Final meeting of AUTOGRASSMILK, farmers, researchers and other stakeholders).

**TASK 5.3 : KNOWLEDGE TRANSFER BETWEEN CONSORTIUM PARTNERS**

**OBJECTIVE:** Exchange of expertise, and the knowledge generated, within the consortium.

**PROGRESS:** The project partners meet at consortium and technical meetings. Consortium meetings have been held in Ireland (February 2013), Sweden (July 2013) and in the Netherlands (November, 2013). Consortium meetings have since been held in France (July, 2014) in the Netherlands (November, 2015), in Denmark (June, 2015) and in Ireland (December, 2015). Meetings of the Exploitation Committee have taken place (when required) in association with Consortium meetings, to discuss issues relating to dissemination. Specially dedicated Technical meetings took place in the Netherlands in September, 2014 and in April and October, 2015. The meetings provide opportunity for consortium partners to discuss and exchange information on a range of issues relating to the project, with a particular focus on project research findings, and knowledge transfer between consortium partners.

**TASK 5.4: COMMUNICATION OF RESULTS TO SCIENTIFIC AND TECHNICAL AUDIENCES**


France: A project presentation was delivered to the standing committee on farm management of the French Dairy Board on 4th September 2013. The main results from the first year of the French AUTOGRASSMILK program were presented at a conference on robotic milking and grazing on the 13th September 2013 (at the SPACE show, which is France’s second largest professional show for animal production: http://ideles.fr/recherche/publication/idelesoir/recommends/les-conferences-de-l'institut-de-lelevage-au-space-2013.html

Four presentations on grazing and AM were delivered at the National Congress on Robotic Milking and Grazing held in Paris on the 10th October 2013. A presentation on the project was also delivered to the scientific unit of the French Dairy Board on the 2nd December 2013.


2014 and 2015:

Workpackage 1


Foley C., Shortall J. and O’Brien B. 2015. Milk production, cow traffic and milking duration at different milking frequencies in an automated milking system integrated with grazing. Presentation from the 7th European Conference on Precision Livestock Farming.


Lessire, F and Dufrasne, I, 2015, Effect of the distribution of maize silage. Presentation


WORKPACKAGE 2


WORKPACKAGE 3

Oudshoorn, F. W., Stubsgaard, A. and de Olde, E. 2014. Pursue applied sustainability in Agriculture. Poster presented at IARU Sustainability Science Congress 2014, Copenhagen,


TASK 5.5: NATIONAL SME-AG DISSEMINATION

The AUTOGRASSMILK project was featured at the TEAGASC Moorepark Open Day on the 3rd July 2013. An open day was held at the AM unit at Teagasc, Moorepark in April, 2014. This was a joint event organized by Irish Grassland Association (IGA) and Teagasc for the IGA members. Approximately 500 farmers attended. The AUTOGRASSMILK project was featured (a full information board/ stand) associated with the EU exhibition at the National Ploughing Championships in Ireland on 22nd, 23rd and 24th September 2014, which was attended by approximately 200,000 people over the 3-days. This is now recognized as the biggest outdoor exhibition event in Europe. The AUTOGRASSMILK project was featured (a full information board/ stand) at the TEAGASC Moorepark Open Day on the 23rd June 2015, which was attended by approximately 7,000 persons.

Belgium: Information on the AUTOGRASSMILK project was displayed on posters at agricultural fairs held in Libramont (26th-29th July 2013) and in Battice (1st-2nd September 2013).

The Netherlands: The AUTOGRASSMILK project was featured in the LTO’s members’ journal, Oogst, in summer 2013. A letter inviting farmers to apply for monitor farm status was published in Oogst in autumn 2013. Research results from the first year of the AUTOGRASSMILK project were also published in the autumn 2013 edition of Oogst. A national farmers meeting on grazing and AM was held in October, 2015 (Symposium Robot and Weiden). Finally, the final meeting of AUTOGRASSMILK WAS ANNOUNCED IN Oogst and held in December, 2015.

Denmark: An invitation for farmers to apply for monitor farm status was published in the dairy farm information journal in August 2013. Two educational events were organized for farmers and advisors in February 2014 on how to improve use of grazing with AM systems.

Sweden: A lecture on AM and grazing was held at the Lely conference in Trondheim on the 27th February 2014, and was attended by approximately 400 farmers. A lecture on AM and grazing was given at the annual meeting of the Regional Grassland Association, and a one day course for farmers (attended by thirty farmers) was held in conjunction with that meeting.

Potential Impact:

The results of this AUTOGRASSMILK project are applicable in many countries, not just the countries that are partners in this EU project. The results are based on different production systems in different partner countries and represent a wide range of production conditions, from pasture-based extensive production conditions aimed at high proportions of pasture in the diet and low feed costs, to intensive production systems with only small amounts of pasture in the diet, aimed at high milk yield
per cow. A number of intermediate production systems are found in-between, systems where both pasture and supplementary feeding are important in feeding and management. A range of the dominant production systems operated in the project participant countries are shown in Table 1 (Appendix 3). The results are based on research performed in countries and regions whose production systems are characterized by a high proportion of pasture in the diet, such as Ireland and Brittany to countries such as Sweden and Denmark, where the proportion of pasture in the diet is quite low (with the exception of organic farms) and many AM farms offer the cows pasture only to provide exercise and recreation for the cows. The extreme diets involve up to a 100% pasture diet in Ireland to a 15% pasture diet in Sweden during the grazing season with associated average milk yields of 5,800 l and 10,200 l, respectively. The project has shown that integration of grazing and AM can be appropriate and advantageous in the different countries despite the differences in production system characteristics. This outcome is a particularly important impact of the project, since the possibility of integration across those differing circumstances was not considered possible prior to the project. Also it is anticipated that the guidelines generated will be useful and appropriate to farmers in many countries, including countries that have not been part of the AUTOGRASSMILK project, since the production systems of many countries fit within the range discussed here (Table 1, Appendix 3).

THE AUTOGRASSMILK PROJECT HAS ACHieved 3 KEY OUTCOMES: (I) IT HAS SHOWN THAT AN INTEGRATED COW GRAZING AND AM MILK PRODUCTION SYSTEM IS POSSIBLE, (II) IT HAS DEVELOPED DETAILED MANAGEMENT GUIDELINES (FROM EXPERIMENTAL RESEARCH) FOR OPTIMUM OPERATION IN VARIOUS PRODUCTION SYSTEMS (INCORPORATING VARIOUS DAIRY COW FEEDING STRATEGIES) IN EUROPE, (III) IT HAS DEVELOPED DECISION SUPPORT TOOLS TO ASSIST THE FARMER IN OPERATION AND MANAGEMENT OF THE SYSTEM FROM BOTH SUSTAINABILITY AND ECONOMIC PERSPECTIVES.

Regarding the impact of this work - the socio-economic impacts and the wider societal implications of the AUTOGRASSMILK project include:

1. The project has created awareness within farming communities in the respective partner countries about the positive compatibility of integrating grazing with AM. Further to this, the project has provided the farming communities with guidelines on how best to practically integrate grazing with AM. This has been achieved by initially determining best practices in the participating countries through experimentation, and then dissemination of the results through numerous farming specific communication platforms including newspapers, magazines, radio, web cast and television interviews, automatic milking monitor farm discussion group meetings, open days in research institutes and on monitor farms, general public visitors to the AM systems in the research institutes, creating YouTube content of results and scientific conferences and workshops.

2. It has been subjectively observed that the uptake of AM reduces the labour demand of the farmer. However, until the commencement of this project it was not known if this effect was similar when AM was integrated with grazing. A trial conducted at Teagasc, Ireland, showed that farm labour requirement was reduced by 36% by AM compared to conventional milking, when both systems were integrated with grazing. This is an important result from the AUTOGRASSMILK project as it highlights that the positive labour reduction associated traditionally with AM is not lost when grazing is also integrated with that system. The labour reduction is not limited to AM in indoor systems but is associated with integrated grazing and AM systems as well. The AUTOGRASSMILK project was featured in on a prime time TV show in Ireland called the ‘Science Squad’ in 2014. This programme featured an interview with an AM monitor famer. In this interview, the farmer stated that the extra time he gained due to the reduced labour associated with AM allowed him more free and available time for family and other activities. Additionally, the extra time available in AM systems may be used to do additional work off farm, which would represent an opportunity to gain another source of income. The labour reduction could also assist the wider community, as farmers would have more time to invest in such community activity. The reduced labour input and the increased flexibility in terms of time of attendance at the robot make this an attractive milk production system. The AUTOGRASSMILK project has highlighted this aspect in countries where AM was not common, e.g. Ireland.

3. The AUTOGRASSMILK project has potential to introduce a significant improvement in operator working conditions on-farm, specifically in relation to milking parlour ergonomics. Many studies have focused on attempting to improve ergonomics in the milking parlour through adjustable floor levels or lighter milking clusters, but the AM system is the ultimate solution to eliminate negative ergonomic situations associated with milking.

4. The results of this project have significantly changed the thinking on operation of AM system in countries where AM has
been common. In many of those countries, it would not have been considered feasible for AM to be operated with cow grazing previously. However, this is now seen to be possible. In the Netherlands, for example, the Dutch farmers association LTO states that “due to the findings of AUTOGRASSMILK (and other projects) on the combination of AM and grazing, the combination of AM and grazing is now possible”.

5. The emphasis placed on the results of the AUTOGRASSMILK project which highlight the positive aspects of integrating AM with grazing, has impacted the mind-set of the companies selling and distributing AM machines. In Ireland, in particular, AM companies are now coordinating discussion groups with AM farmers which meet on a regular basis to discuss grazing management and strategies, so that farmers can learn from each other and discuss ideas. This is likely to have a positive impact on the number of people considering investing in an AM and thus benefiting from associated positive factors, such as improved lifestyle or income through off-farm work.

6. EU legislation contains provisions on general animal welfare, with Article 3 of Directive 98/58/EC stating that “Member States shall make provision to ensure that the owners or keepers take all reasonable steps to ensure the welfare of animals under their care”. All societies have a responsibility to ensure the welfare of animals. It is generally accepted that natural behaviour, freedom of choice, exercise and direct exposure to fresh air and daylight greatly improves the health and general welfare of dairy cows. Grazing gives much more scope for natural behaviour compared to conventional cubicle houses, and AM allows cows to be more in control of their own time budget and movements. Thus, an integrated grazing and AM programme, the central focus of the AUTOGRASSMILK project, should provide cows with a positive experience.

7. The aesthetic qualities of the communities within which dairy farmers traditionally practise grazing are maintained when farmers can continue grazing with AM. The AUTOGRASSMILK project has improved the perception of AM through emphasising the positive effects of integrating AM and grazing. Grassland is associated with lower inputs of pesticides and fossil fuels, and grassland in general is seen as having a positive impact on landscapes. Thus any strategy that ensures greater use of grazed grass is a positive.

8. The inclusion of pasture in the cow diet and time spent at pasture can have positive effects on sustainability of the system, such as milk quality and cow health. AUTOGRASSMILK has a positive effect on the current and desired EU thinking of producing milk with positive health attributes. Results of AUTOGRASSMILK will impact positively on EU policy on overall sustainability through providing a sustainability assessment tool which is available to dairy farmers to evaluate their own production systems.

9. The technology involved with AM is attractive to new entrants and a younger generation of farmers. It has been observed in e.g. Ireland that the volume of new entrants and young farmers that are opting for AM has increased recently, especially in light of incentives for new entrants. A concern with this trend is that these farmers could have the perception that the technology within the AM machines would provide all the answers and make all of the management decisions for them. However, farming knowledge and ability needs to be earned and learned through experience and interaction with country specific advisory networks and farmer groups. Because of the structure of this project, that is, inclusion of SME Associations, it allowed a direct dissemination and close interaction with farmer members, including new entrants and young farmers, on the challenges and guidelines on integrating AM and grazing.

10. The knowledge generated in the AUTOGRASSMILK project will facilitate future planning by people with land a distance greater than that recommended for cow walking on a twice daily basis. AM would allow the setting up of an independent parallel milking system on land that is a considerable distance from the existing farm, which can operate independently and with minimal labour demand. This function of the AUTOGRASSMILK project will be useful where the dairy sector expands, while at the same time fragmented land bases prevail.

11. A further impact of AUTOGRASSMILK, particularly within Ireland, is the unbiased perspective on the information that is being disseminated to end users. Until the commencement of the AUTOGRASSMILK project, the primary source of information that farmers had access to was personnel of the AM companies. Since the AUTOGRASSMILK project the information that is now available to farmers in Ireland is unbiased and based on experimental evidence.

12. Impact on European competitiveness in dairying - the results achieved in AUTOGRASSMILK will contribute to improving the economic position of EU dairy farmers both individually and collectively. In Ireland specifically, each tonne of additional grass utilised increases farm net profit by €267/ha. While this figure is not representative of the situation in other participating countries, the recognition of grass as a cheaper source of feed is true in most of the countries. In the Netherlands, grazed
grass is considered to be €0.1 cheaper per kg dry matter than ensiled grass. In Denmark, consumers and the dairy industry are willing to pay a considerable premium for milk from cows which have been grazing. Any change in farm revenue will have a consequential effect on farm incomes, as well as increasing employment in dairy-related manufacturing companies, such as those engaged in the production of AM equipment. Changes in employment and income levels are other indicators of socio-economic impacts that have wider societal implications. An unbiased evaluation of return on investment of an AM/grazing system and a conventional milking/grazing system was conducted for large and small herd sizes and medium and high specification conventional machines. This provides solid economic information for the different options over a 10-year repayment period, and provides an economic decision support tool to the potential investor.

13. The AUTOGRASSMILK project does promote automatic data collection (through the AM unit). This does provide herd managers with data that will enable them to make effective management decisions, and be proactive rather than reactive in cow management. Early detection of metabolic and reproductive disorders, lameness, and mastitis does allow for faster and less expensive treatment, shorter recovery time, improved animal welfare and more efficient use of labour. This is important in all countries, but especially in the countries with high yielding dairy cows, like Sweden, Denmark and the Netherlands.

14. The AUTOGRASSMILK project allows for promotion of collaboration within the EU countries. It specifically involves the integration of two different concepts (AM and cow grazing). Thus, it meant the transfer of grassland management knowledge and technology, and AM knowledge and technology between the countries of the consortium. Thus, the AUTOGRASSMILK project represented an exemplar of transnational technological cooperation. The AUTOGRASSMILK project is also a consortium of small and medium sized collaborative groups, in the form of the SME-AGs of the different countries.

15. The involvement of monitor farms has increased confidence of the outcome of the project, as ‘real’ data from such farms has been repeatedly presented as part of the project outputs.

16. The sustainability and economic decision support tools developed within the project will have significant impact on choosing alternative management strategies. Alternatively, the tools and guidelines on grazing management should be very useful to farmers.

17. The impact of AUTOGRASSMILK will be largely through the different forms of dissemination and exploitation. They include: open days in research institutes and on monitor farms, monitor farm discussion group meetings, visits to AM units on research farms, workshop sessions dedicated to AUTOGRASSMILK, conferences with dedicated sessions to AUTOGRASSMILK, presentation of results in technical publications and popular press, as well as radio, web-cast, you-tube, website and television. Additionally, SME-AGs disseminated the results specifically to their farmer members.

Sustainability is a particularly critical parameter for all future animal production systems. With regard to sustainability in AUTOGRASSMILK, all partners became more aware of the task of weighting of the dimensions (economy, environment, society and governance) (and the risks associated with those) into one final sustainability verdict. The AUTOGRASSMILK tool did not average the dimensions. The initial research asking stakeholders which dimension they found most important was interesting but could not be used to weigh the dimensions. The process indicated that a more complex approach was required, where themes were also investigated. Sustainability at farm level is a relative state of the art; relative to the context, which can be local, national, timely, or towards other sectors. Sustainability is dynamic in the sense that it is intrinsic to development. The sustainability assessments made for the monitor farms have been discussed in the local SME associations with their members. It will be debated over time, if the values found in the AUTOGRASSMILK tool, using weighting values and reference values, are the most appropriate. These discussions and debates are valuable, both for the process of understanding the connections of the different dimensions and themes of sustainability, but also for making possible trade-offs. For example it might be more important for a farmer to save time, than to save the climate, although they might counteract. By making a sustainability assessment, and testing different options, it is possible to see how one aspect (indicator) would influence another. In addition it is possible to identify where a farmer should focus, as the use of reference values generated by experts of the country gives an indication of the farms performance. Assessing sustainability has contributed to this process, discussing the coherence between different performance indicators e.g. animal welfare while grazing and indoors, but also the possibility to develop sustainability by using innovative technology.

During the process of gathering the data on the monitor farms, repeatedly it was mentioned that the farmers were interested in the results and interested in discussing these results with the advisors that had collected the data, and with the...
researchers involved. This has been done in different ways in the different countries (see webpage, Results and Deliverables). AUTOGRASSMILK has from the start not had the intention of comparing the monitor farms or the present state of the art between countries. It is however interesting to see how the monitor farms in the different countries, showing a range of possible AM solutions, score on the different dimensions, when using the country specific reference values. The intention of the project was to learn from each other’s experiences and from national adjustments of dairy and grazing to the automatic milking. Historical reasons have caused different speeds of introduction, and also cultural differences between the countries will endorse the fact that AM is not equally used among the European members. When the project started in 2013, it was in light of the problems arising with grazing that AM was introduced. During the last three years, AUTOGRASSMILK has been an important actor in the awareness and knowledge generation on combining grazing and AM.

A large number of farmers have shown very significant interest in the integrated grazing and AM system in Ireland and this is almost all due to the establishment, operation and information outputs generated by the AUTOGRASSMILK project. A total of 1,438 (492 in 2013, 455 in 2014, 291 in 2015) farmers individually requested to visit this integrated milking system at the research Farm (this was in addition to other visiting groups). It is also true that significant interest has been shown by farmers in the other participating countries. AUTOGRASSMILK has certainly ‘put out’ the message that cow grazing can successfully be operated with AM.

Specifically in the case of the Netherlands, the consensus within the SME-AG (LTO) considers that dairy farming in the Netherlands has to be developed into a sustainable sector, which is highly valued by society. Grazing is an important part of this, because grazing makes dairy farming visible and cows in the field are a highly valued characteristic of the Dutch landscape. In addition, grazing is also important for animal well-being. Due to increasing herd size per farm, more fragmented land parcels and an increasing number of farms with AMS, the percentage of grazing cows is decreasing. Therefore, projects that assist in maintaining cow grazing in the milk production system are important for the Dutch dairy sector. The ‘Convenant Weidegang’ (covenant grazing) is an agreement of 66 parties in the dairy sector aimed to give a new impulse to grazing, in order to at least maintain the current level of dairy farms with grazing (2012: 81.2%) and increase the incidence of grazing if possible. The role of LTO in the ‘Convenant Weidegang’ is to gain and share knowledge about grazing. LTO’s reasons for participating in AUTOGRASSMILK were:

- possibility to gain (international) knowledge on the combination of AMS and grazing,
- make practical tools for farmers to make grazing easier and
- possibility to spread the new knowledge.

In the Netherlands, there were two other projects that recently focused on grazing (as well as AUTOGRASSMILK). Due to the findings of all three projects it is now possible to say: “the combination of AMS and grazing is possible!” After several years of a decline in grazing, the sector has managed to achieve a slight increase in 2015 (Figure below), but the challenge to increase grazing further remains. Research within AUTOGRASSMILK subscribed to the opinion that AMS in combination with grazing is possible. The decision support tool and some other tools will help farmers in making decisions about grazing. Some of the research is about technical support for grazing which requires some further input in order to make it ready for on-farm application. It is considered by the Dutch project participants that the research of AUTOGRASSMILK has contributed to future technologies for grazing that will be beneficial for the Dutch dairy sector. Figure 1 (Appendix 3) shows the extent of grazing in the Netherlands in the period 2012-2015 (% farms that practise grazing).

Specifically, in Belgium, the number of AM units has increased in recent years. The positive image of grazing for consumers and its positive impact on the environment are very important in the public opinion in Belgium. The AUTOGRASSMILK project has certainly contributed to the promotion of grazing there. Increasing numbers of farmers are discussing the possible combination of AM systems and grazing with the milking equipment companies. The project has demonstrated through the experiences of 4 monitor farms that grazing cows can be milked automatically in Belgium. It was observed that the farmer meetings and workshops held during the project enhanced both dialogue and exchange of skills between farmers. This aspect of the project had a very positive impact on farmers who had previously been attempting (with difficulty) to conduct some grazing on their AM farms. These meetings proved to be very helpful for farmers in interacting with AM advisors and hearing the experience and discussions with monitor farmers who had focused on improving cow traffic to the AM unit while cows were at pasture, during the project. A further impact of the project was that farmers gained a better awareness about the costs linked to AM. Furthermore, the use of a mobile AM unit was demonstrated during the project at the experimental farm of Sart.
Tilman and that had the added impact of attracting visitors from other countries (France, Luxembourg). People were informed of the positive and negative aspects of mobile AM, for example, allowing dairying on fragmented land bases but at a higher cost. It is considered too, that the project has provided the opportunity to focus more on the different sustainability pillars, as the development of the sustainability tool was an integral part of the project. Specifically in Denmark, SEGES (SME AG) and Aarhus University have used and will continue to use the knowledge and experience generated in the AUTOGRASSMILK project in national conferences (yearly dairy conference), field meetings (experience groups) and grazing schools (courses set up in regional SME-AGs) to promote the knowledge in grazing.

In summary: AUTOGRASSMILK has provided the means to short term impacts such as the availability of high quality information material and tools to farmers and dairy advisory centres on AM and grazing. It has provided and will continue to provide the means to long term impacts such as increased productivity in AM herds with grazing and increased numbers of AMS herds considering grazing as a realistic opportunity. The positive impact of AUTOGRASSMILK may also be observed by the fact that a 5-7 year follow-on research programme is now being put in place at TEAGASC due to the results from AUTOGRASSMILK and the perceived interest in an integrated grazing and AM system as highlighted in AUTOGRASSMILK.

Possibly, the greatest impact may be observed in the different approach to the question “is grazing possible with AM”? Before AUTOGRASSMILK, the answer was “not sure - it would be very problematic with regard to cow traffic”, but after AUTOGRASSMILK, the answer is “yes – following research in cow feeding regimes and grazing, technological factors and integrated system management, it has been demonstrated that integrated cow grazing and AM works in practice, and guidelines are now developed so - you can do it by......”.

List of Websites:
www.autograssmilk.dk

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| Result In Brief          | Sustainable grazing and automatic milking |

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