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Preface

Within the framework of my European Engineer Degree (EED) specializing in livestock production, I had an opportunity to do an internship abroad (I am French). It was a great way to discover a new culture and a new agricultural system of production. This placement took place from September till December 2018 with the Irish company: Grasstec.

Grasstec is situated near Cork, the second largest city in Ireland. This company specializes in advising breeders, and more particularly around the grassland layout as well as farm buildings. Having about twenty years of experience, Grasstec has become a leader in farm mapping and farmyard design across Ireland and The United Kingdom.

For my part, I wanted to know more about the influence of several systems of pasture on the sustainability of Irish farms. So in this report, I am going to focus on meadows, systems of present grazing in Ireland and finally highlight the consequences of a grazing system on the sustainability of farm.

Being very interested in the cattle production (beef and dairy), I was able to focus on the grass management. I grew up in the agricultural world as my father is a farmer, breeding beef cattle (limousines) and rabbits. So, I hope in the future to have the opportunity to put the knowledge I have acquired during this internship into the family farm and share it with other farmers, French or not.

Finally, I would like to thank all the people who have helped me during my placement within Grasstec, their welcome, their support and their patience. All this in a very pleasant atmosphere. I would also like to thank my teachers for their support before, during and after this placement.

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1. Introduction

a) Agricultural development in Ireland

Nowadays, Ireland has around 140 000 farms and most of these Irish farmers specialize in dairy production. The growth of grass is important as it is the principal foodstuff for producing milk cheaply. One litre of milk costs the dairy farmer between 20 and 30 cents, compared to 35 cents in France for example. Moreover, the lifting of quotas in 2015 allowed Irish farms to increase their milk production having been subject to several years of limits. (Teagasc, 2018)

Grass growth is, therefore, so important in order to produce low cost milk. With, often, more than one thousand millilitres of rainfall and a temperature that rarely exceeding 25°C, the weather allows for good grass yield per hectare. Each year the grass growth is different, but yields are between 10 and 20 ton of dry matter per hectares. Compared with France, where yields are rarely higher than 10 tonnes of dry matter, but nearer to 7 tonnes of dry matter. The map attached shows several dry matter yields per hectare across Ireland in 2015. (Micheál O'Leary, Anne Geoghegan, Michael O'Donovan, 2016)

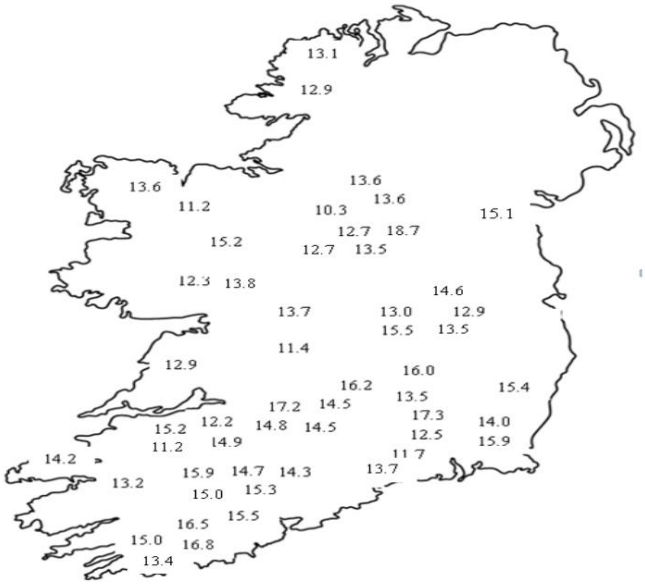


Figure 1 : DM yield/ha in Ireland; Teagasc; 2015

b) Grazing notion

Before learning more about grazing, it is important to know about grass, how it is grown and the different life stages of a grass plant. It grows in two stages.

The first one is the vegetative stage where the seed germinates in the soil and then we see the growth of roots and the first leaves. The roots develop in order to reach the resources of the ground (water and nutrients) and therefore increase the durability of the plant. Leaves grow and proliferate in order to exercise their main role: the photosynthesis. Plants naturally use photosynthesis to produce energy (glucose) which is used for its growth. The photosynthesis takes place during daylight and allows the transforming of atmospheric carbon into plant tissues when the plant is correctly fed with nitrogen and other minerals.

After the vegetative stage, there is the reproductive stage. For this to occur the grass plant requires grows to earing, at this stage new seeds can be produced, which fall on the ground and begin another cycle. The cycle of one plant can be long, some grass species do not live after the first cut (example: red clover) and other plants can undergo several cuts (example: English ryegrass). (Harris, 2004)

Meadows are very dependent on soil and climate conditions. It is necessary to know that the growth varies according to the season, in winter for example the meadow will be dormant according to the varieties sown. The lack of growth corresponds to the minimal temperature after which the plant puts itself in "rest" and thereby stops its growth. The lack of growth of a legume will be close to 5-6°C while that of a gramineous is toward 0°C. That is why gramineaous generally get the upper hand over the legume at the beginning of the spring because they begin their vegetation earlier, but the growth of legume rhizomes will be better during the summer when the temperatures are higher. The peak growth of a meadow is reached generally around May, at that time the dry matter yield will be highest.

In the case of temporary meadows, the choice of species of a meadow is made according to several factors, and aims at increasing the potential of a pasture. The breeder will want a good yield on dry matter to feed of his animals, making his stocks last for the winter (production of hay, wrapping or still silage) and to be able to maintain the stability of his animals and the milk production. So, it is often advised to sow several species in the same plot of land because these multi-species meadows will have more impact on the meadow such as:

- Saving the nitrogenous fertilization and improve the protein content thanks to legumes
- Resisting the climatic hazards and produce feed all year round
- Having a balanced diet (balance energy/protein)
- Allowing to have a quality stock in winter
- Maintaining or improving the ground structure

When sowing, the farmer has the choice from a multitude of species, generally classified between 2 large families: gramineous and legumes. Broad based gramineous will fulfil the energy requirements for a ration for a cow. We find various ryegrass, fescues, dactyls, timothies there, etc. As their growth begins earlier in the year, the farmer can use and takes advantage of early grazing when the energy level is high.

If the quantity of feed increases, the quality of feed (energy and protein) is going to lower in value. There is a big variety of gramineous, but English ryegrass is sown most of the time, because it is

more flexible to exploitation and it can easily endure the footfall caused by animals during pasture. However, it has problems growing during high temperatures. (Department of Agriculture, Food & Marine , 2015)

As for legumes, their main purpose is to bring some nitrogen (protein) to the animal, as well as to the ground where it is planted. It is, however, necessary to pay attention to bloat (inflation of the belly due to an abnormal accumulation of gas), particularly alfalfa which can be difficult grazing (only in multi-species meadow like “Swiss mixtures” or after 5 years where it becomes less rich in nitrogen). Therefore, the alfalfa is more suitable for mowing. We can also find white clover in our meadows which is adapted to grazing, contrary to the red clover which will have a single growth in its life and disappear after the first harvest. (Brochier, 2018)

c) *Different types of grazing*

A milking cow can eat around 17 kgs (dry matter) of grass per day. (Teagasc, 2017) Otherwise it must have one acre for 37.5 milking cows per day or one hectare for 92.7 milking cow per day if the grazing cover is around 1500 kg of dry matter. We can see according to the different farms several systems of grazing management. Each of them has their own advantages and disadvantages…

- Stock grazing:

The simplest system is stock grazing. It is enough to put animals on the plot of land, sometimes limited by hedges, and to take out the herd when there is no more grass. It is necessary to be vigilant putting grass aside in case of high temperatures when there are growing difficulties. This system has the advantage of limiting the footfall caused by animals, to exploit the grass before the earing if the height is controlled, to eliminate the constraints bound to the movement of animals and drinking troughs, economies in fencing and finally it is the system which is the least binding in terms of time to the farmer. The following diagram with images gives an idea of the stock grazing system:

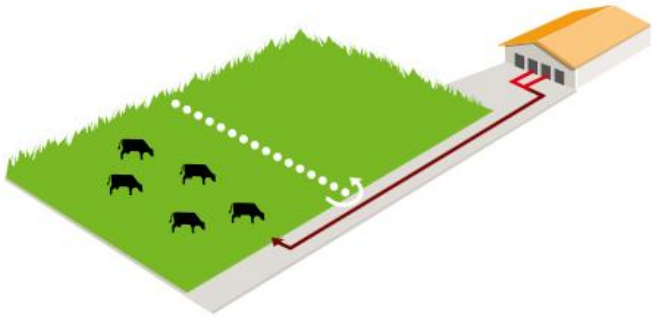


Figure 2: stock grazing; Wageningen; 2017

- The rotational grazing:

The rotational grazing involves the division of a field into several paddocks according to the farmer's wishes and the size of the herd. The herd will stay for a short time in a paddock, and the breeder will close it, and will open another when he considers that it is necessary to change. This system can be more or less flexible because it is the farmer who choices to move his animals every 24 hours or 36 hours for example.

The constraints of this system are the amount of fencing to be set up and maintained, the layout of water distribution, the standing about of the animals which can really damage the wetter meadows, the risk of trampled grass, if it is too high, at the entrance of each plot of land (it is highly recommended to mow when the grass reaches 15 centimetres) and the daily production is not regular.

There are assets as well. This system allows uniform formatting of fragmented ground, to correspond the plan of manure to the degree of intensification that is going to undergo in the paddock in the following annual planning. Finally, to fit the size of the paddock to the herd and so graze two paddocks at the same time or as previously said to mow if the rotation is long. (The Pasture Project, 2016) The diagram below shows how the rotational grazing can be set-up:

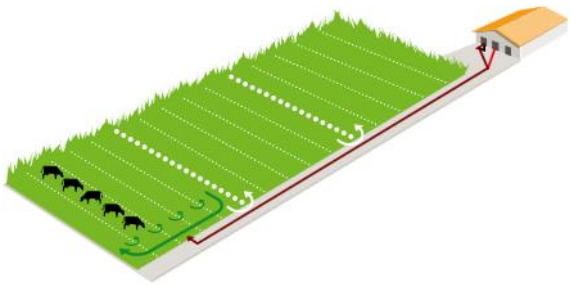


Figure 3: rotational grazing; Wageningen; 2017

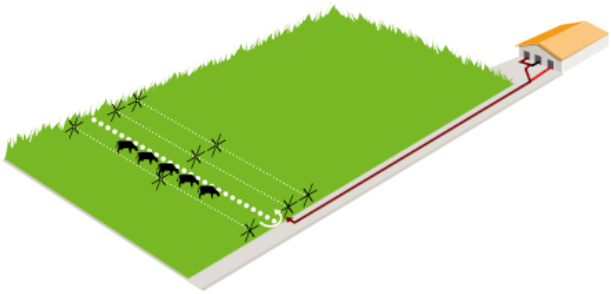
- The strip grazing:

The strip grazing is characterized by the presence of a wire fence which moves forward according to the quantity of grass in the paddock where the herd is. The breeder can even add a wire fence behind the herd to push them and incite animals to go towards the newer grass. Naturally the moving of the wire fence is done according to the size of the herd and the availability of the farmer.

The down-sides to this system of grazing are the hard work, the footfall, the access to the water, the overgrazing below the wire fence and the need to have paddocks of a shape as rectangular as possible. The benefits, wasting is minimal even non-existent with this system, because the breeder can choose from day to day how long they leave animals in the paddock judging by the state of the grass. This system can be very flexible, if the farmer is busy, he can move the wire fence farther than planned

increase the area pushing out the deadline for the next movement of the wire fence. (Freeman, 2014) This diagram shows how the strip grazing system works:

Figure 4: strip grazing; Wageningen; 2017



- Robotic grazing system:

Nowadays we see more and more robotic milking system, farmers equippe themselves with automated milking robots where cows can go to be milked when they wish. It is possible to adapt the milking robot to a system of successful grazing. However it's better to have good grassland around the milking parlour to avoid too long a distance between the pasture and the milking parlour, underproduction being the consequences. In certain farms, roads have to be crossed which can prevent access to the paddock. To deal with this, some farms have no hesitation in creating tunnels so that cows have free access, or then to move the milking robot via a trailer. (V. Brocard, I. Dufrasne, F. Lessire and J. François, 2015)

Figure 5: underpass; FARMIreland; 2018

Figure 6: milking robot trailer; Warsaw; 2015

To best manage his pasture and his system of grazing, the farmer needs to have all eyes on a number of factors including the quantity and the quality of his grassland. For this he can use a grass plate meter which allows him to know the present quantity grass in the paddock. He can also be organized thanks to a pasture calendar where he can note the data collected by the grass plate meters, plan the dates of entry and exit of animals from the paddock, also the dates when he can mow them and the contributions of fertilizers (organic or artificial fertilizer).

Moreover, the more we respect the life cycle of the grass plant the more we are going to improve the yield. If the farmer takes out the animals at the best possible time, there will be enough

leaves for the photosynthesis which will boost the development of the plant. On the other hand if there is over grazing, there will not be enough leaves for the photosynthesis and it will take longer for its growth. Finally, the farmer has to choose his system according to his objectives. If he wants to reduce his workload, it would be best to advise him to go towards the stock grazing or the little dynamic rotational grazing, as it is less time consuming, as against the dynamic rotational grazing or the strip grazing.

Finally it is important to have the best roadway system to assist the herd movement, mainly between paddocks and the milking parlour. We feel that it is necessary to have a width of 4 metres for a herd of 100 cows, and 5 metres for a herd of 200 cows. In the case of a robotic milking system, a roadway of 1.5 meters wide is enough. It is also important that the roadway is stable and in good repair to avoid any risks which may hurt or cause lameness to the animals resulting in a reduction of milk production. So it is advised to have a roadway system with a hard surface (concrete or tar) and to clean it regularly (scraping) in order to have a good well-maintained road. (Teagasc, 2017)

d) Water infrastructure

Water requirements vary according to several factors. First of all, a cow in full lactation will obviously need a bigger quantity of water than a dry cow. A milking dairy cow can drink almost 200 litres of water each day, therefore it is really important to have a system of effective water distribution. These drinking points should not be situated more than 300 metres from the paddock where animals feed because there is a risk that the herd will remain near the drinking trough which may cause a loss of productivity. (Dairy Herd Management, 2011)

The amount of water has to be proportional to the size of the herd as it is necessary to avoid dehydration. In an ideal situation the water trough should be located in the middle of the paddock to allow the cow access water from all sides. If the trough is situated under electric wires, it can reduce the drinking space, as cows will be reluctant to drink right beside an electric fence. It is also possible to create a traffic lane leading to all the plots of land accessing the water source. In conclusion it is important to invest in a good network of water to facilitate the amount of water available. (Ryan, 2009)

e) Grazing risks

When a layout is set up well, there are certain risk factors to be considered. Parasites can be found in wet meadows such as liver fluke or lungworms, which can impact on the production of the animal, therefore have an impact on income. Farmers can give an anti-parasitic to susceptible animals that graze in these high-risk areas. (COWS cattle parasites, 2014)

The breeder can also make his winter stocks can be adapted by the farmer according to the time and the numbers of animals spend in stalls. It is recommended that the breeder estimates his needs as soon as possible to get organized better and establish a grassland calendar. When calculating winter needs, the breeder has to establish, if possible, a safety margin to take into account a likely drought causing a decrease of his stocks.

f) Maintenance of a pasture

During the year, a meadow can undergo multiple attacks in particular with regard to the grazing (standing about, over grazing, etc.) and then to weather conditions (drought, hydromorphic, frosts, etc.). The maintenance of pastures allows a limiting of the impact of all these attacks, to obtain a quality grass, at the same time protecting the longevity of the present species. To spread dung, to scarify, to roll, to eliminate adventitious, in favour of tilling grasses, to mow residuals, to realize an over seeding,…

The list of meadow problems is rather long so now we will look at the solutions:

- Mowing of residuals can be done after every grazing when possible and when there is obviously a presence of residuals. If the pasture is badly laid, we see systematically grass clumps still standing after the passage of animals, because these grasses are generally not palatable for cows. If they are not mowed, there are risks of regrowth of the adventitious in the paddock, which later on can to be even more difficult to eradicate. (WSU Clark County, 2014)
- Dung spreading allows better distribution of fertilizer, in particular nitrogen in dung in the pasture. If the dung remains intact, there is a risk of having an excess of nitrogen centered where the dung is present, consequently there is a risk of an overgrowth of grass and thus the presence of residuals after pasture. This must be done at the correct time in a well grazed meadow where the next grazing will begin at a planned future date. The ideal is that spreading must be followed by rainfall to clean the grass and avoid the grass being unpalatable for the cows. (WSU Clark County, 2014)
- Over-seeding allows to reintroduce species which lost their densities and their productivity within the paddock in the course of grazing. That way it keeps the nutritional potential in the paddock, especially to protect the load-bearing capacity of the ground. (Teagasc, 2017)
- The passage of an aerator on the ground can also be done to allow the oxygen, the water and the nutriments more easily reach the root systems, to improve the structure of the ground, allow the roots to go deeper (consequently to decrease the contributions of fertilizer) and finally to improve the absorption capacity of water. (Walter Watson, 2015)

This maintenance must be carried out at the best available time to avoid additional costs of production. It is also necessary to take into account the maintenance of fences. To prevent animals from changing paddocks on the own without the wish of the farmer and afterwards causing certain problems in the system, or even the animals going on to public roads and causing accidents.

g) Sustainability notion

The sustainability notion is often connected to the sustainable development. By definition, the sustainability refers to the economic growth and the long term perspective. Therefore, the environment and the social aspects have to integrate into the development process. We usually say the sustainable development is based on 3 dimensions: economy, social and environmental. To explain that, we can use this following scheme where preoccupations are shown. We can see the notion of durability in the confluence of three dimensions, when all three are respected. (Mason, 2016)

Figure 7: sustainable development scheme; Quora; 2018

We can also speak about sustainability in the agricultural world. Indeed if the common objective of all farmers is to have a sufficient income, the social and environmental aspects take more and more time of the farmer.

- Economic dimension

As previously said the objective on a farm is that the laborer is paid according to the work realized upstream. Most of Irish farmers can keep a yearly record where they can see how their exploitation evolves in time and space. That means the farmer is going to be able to analyze their economic results from one year compared with another one, but also compare with the average groups to know if the exploitation is successful or if it can make improvements.

When he is going to analyze the economic and financial situation of the exploitation, he looks particularly at the profitability (gross margin, return on investment), the solvency (own equity,long term payment) and the liquidity (cash-flow). The ratios to express the profits are most often (CFI, 2015):

- Gross output = sales
- Variable costs: vet, concentrate, fertiliser, etc.
- Gross margin = revenues – costs

- EBT (Earning Before Taxes) = Gross profit – Depreciation/Amortization - Interest
- Net profit = EBT - Taxe

For example, the Teagasc* client can receive the “Teagasc e-Profit Monitor Analysis” where he can find all of these things quoted previously. (Teagasc*: state agency providing research, advisory and education in agriculture, horticulture, food and rural development in Ireland)

- Social dimension

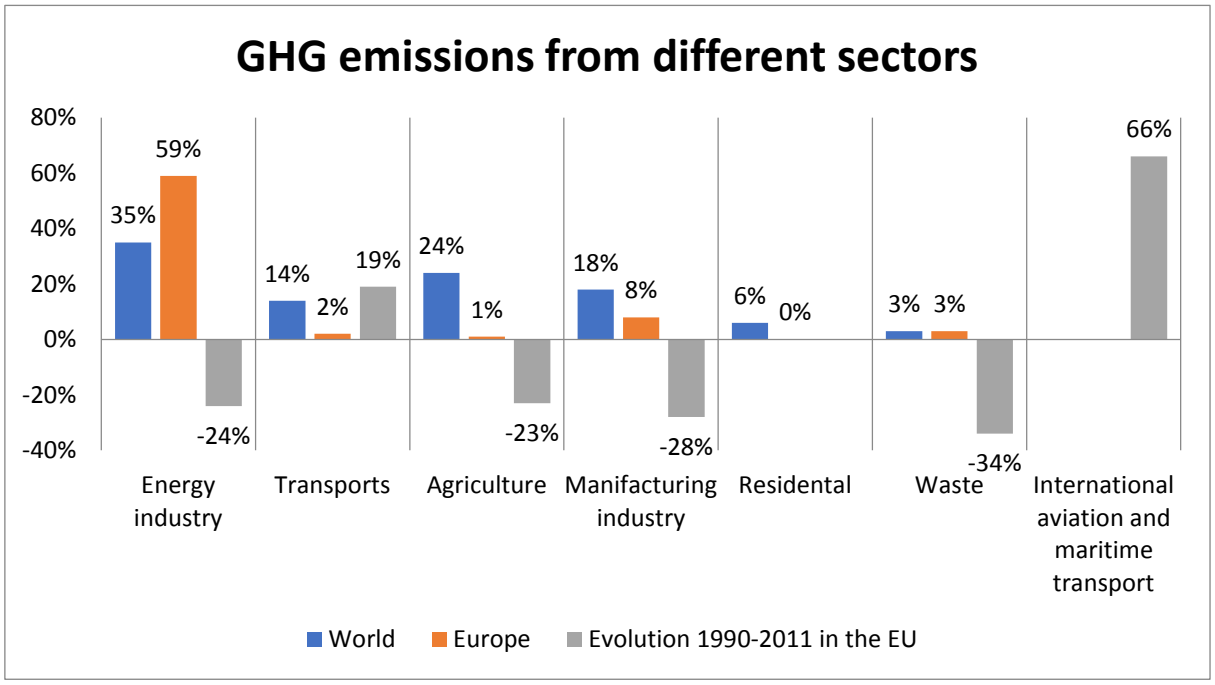
Then we can divide the social dimension into two parts. There are the professional aspect with the industries and the consumers. That means it is important the farmer knows the issues and demands of the food-processing industry and particularly the consumers.

There is the private aspect, which means the farmer has to get enough free time for his family/friends and his activities (hunting, sport, association, etc.).

- Environmental dimension

The environment dimension is certainly the most important aspect because of the global warming, each sector of work has to progress in order to reduce its impact on the environment.

The agriculture/forestry is responsible 24% of greenhouse gases emissions in the world, but only 10% in Europe. Moreover, inside the European Union from 1990 to 2011, emissions from agriculture decrease by 23%. In the following graph, we can see all sectors compared with the agriculture sector: (European Environment Agency, 2018)



Nowadays, the biggest problem in dairy production is the emission of greenhouse gases, especially methane gas. Indeed, this gas is produced during the organic matter digestion, therefore by ruminants (monogastrics cannot or very little digest organic matter).

Indeed, organic matter or cellulose is chewed by animals, and then these strands will join the rumen where they will be digested again by different bacteria, fungi and protozoa. Following this, we obtain volatile fatty acids that will be absorbed by the rumen walls, and on the other hand we will get hydrogen (H_2) and carbon dioxide (CO_2). The metagenesis bacteria (anaerobic bacteria) present in the rumen will create links between these different molecules and produce CH_4 molecules, more literally methane and water molecules ($CO_2 + 8\ H \rightarrow CH_4 + 2\ H_2O$). This whole process is called enteric fermentation.

This methane escapes into the air in the form of burping or within dung. Nevertheless, the methane present in dung is considered as potential emissions, because if the methane wants to access the atmosphere, it will need a favourable environment (anaerobic) like accumulated bedding. But in most cases of Irish farms, the herd stays almost all the year outside, at the grazing. So, this anaerobic environment cannot unfold. The methane is then emitted only in the burping shape. (Teagasc, 2017)

Then, the farm also contributes to the depletion of fossil fuels resources (heating, mechanization and electricity), the degradation of the quality of the water because of the spreading of manure or fertilizer and finally, according to some people, farm is suspected of depriving certain surfaces which could be intended for the feeding of the human population. It is not rare any more to see groups of people who wish the abandonment of animal breeding, or then to see messages in the social media of the type: “by decreasing your consumption of meat and milk, you could protect the environment”. (Teagasc, 2017)

However, the dairy/suckler farm itself has the capacity to store carbon, especially through pastures and hedges. Indeed, if plants produce carbon dioxide following cellular respiration, it will also store this carbon during the photosynthesis. Indeed, the photosynthesis takes place during the day in the presence of light and it allows the transformation atmospheric carbon into plant tissues when the plant is properly fed with nitrogen and other minerals.

So, it is necessary, in this case, to talk about “net carbon footprint” and not emissions. But today this carbon footprint is difficult to calculate because there are a lot of factors to take in account.

The farm allows the consummation of waste by products from the production oils for human consumption. Therefore it is important to question the idea that the farm deprives certain land surfaces which could be intended for the production of food for human consumption.

Farming practices of today are not the same as those of 30-40 years ago, farmers are the first ones to know that their environment is their main working tool, and as any working tool, it is necessary to maintain it.

There are several labels and plans as “Origin Green Ireland” or “the Dairy carbon plan” which allows putting forward the farms which are approaching of environmental durability. So we can estimate the contribution of farm effects for the environment thanks to observing hedge linear, part of meadow permanently in the crop rotation system, the fertilization, and many other agricultural practices.

So we can say that there are many economic, social and environmental challenges in today's agriculture. These issues can be put to use on several scales: at the international level, of a country, of a region, of a farm or even of a paddock. The main objective is to find the production system which would be the most economically viable, the most livable and the most environmentally friendly.

h) Knowledge gap

So, now that we know more about grazing management and what it includes, as well as on the sustainable development, the aim of this thesis is to focus on the impacts of grassland management on the farm sustainability. Indeed thanks to this introduction we were able to learn more about the cycle of a meadow, the various types of pastures, what can be done to improve the meadow and finally what the sustainable development means in general and within the farming world.

In the case of Ireland, the grass allows to produce cheap milk and thus to have a cost price low to benefit from a rather larger gross margin in most Irish farms. Could we still decrease these loads by changing the strategy of pasture, for example? Or on the contrary, can the fact of intensifying its system go against the sociological and environmental challenges of the farm in question? This takes us to the main question of this thesis:

"How can the farmer correspond his grazing system to his farm's challenges?"

By this main question, we would like to know which parameters the farmer has to take into account to improve the sustainability of his farm according to the means available to him. Some sub-questions will be directly bound this main question such as:

- What are the main objectives of the farmer?
- Which are the most important challenges for a dairy farmer in Ireland in the near future with respect to:
    - Economic perspectives
    - Social satisfaction
    - Environmental protection

2. Material and method

a) Material

The objective of "the material" is to describe entities, the people who are going to be questioned. In the case of this thesis, it was several dairy farmers who were questioned, more exactly there were 14 farmers. Most of these farmers come from Munster (57% of farmers), but also Leinster (29%) and Connacht (14%). All these farmers breed dairy herds, but there are 2 of them who breed beef herds as well.

b) Method

The "method" is a term that means which variables will be measured and how the measurements will be realized. So, this collected data is of qualitative and quantitative. Indeed, to facilitate the collection of data, I used the SurveyMonkey software. This software allowed me to make the survey short, the survey was composed of 33 questions and the average time to fill it was 6 minutes, thanks to using of different forms of questions. I synthesized my survey, as well as possible, to get more answers. If, the survey was too long, farmers who receive the survey by e-mail (or Facebook) would not have answered for lack of time. Given that some data was personal, the questionnaire was anonymous.

As it was said previously, the survey has been sent to farmers by mail. My company coach and some of my colleagues gave me around 30 contacts that were more likely to answer me. I also shared my survey within a Facebook private group. This group is called "Irish Farming Discussion Group" and gathered around 33 000 members, most of them are Irish Farmers but there are some French or British farmers as well. The survey was composed 5 different parts:

- Farm presentation (4 questions)
- Grassland presentation (10 questions)
- Farm economic situation (5 questions)
- Farm social situation (3 questions)
- Farm environmental situation (5 questions)
- Farm evaluation (6 questions)

The survey is present in the "Annexe n°1: Survey used for the data collect". In order to facilitate the collect of answers, most of the time, I made available multiple choice or cursor or evaluation by stars. I tried to avoid "textbox" as much as possible in order to simplify the analysis.

3. Results

In this part, all data collected will be present, but without any analyses done. This data comes from 14 questionnaires and mostly from 14 Irish farms. All farmers filled the survey as they could, but some of them did not answer all questions.

On the blue line, we see the question number and the title of the question and the number of farmer who answered the question. Sometimes, we see "upper quartile", it shows the quarter of the dataset with the highest values. Conversely, the "lower quartile" shows the quarter of the dataset with the lowest values.

a) Introduction of the sample

Question 1	Where are you from?	14	
	Munster	8	57,14%
	Ulster	0	0,00%
	Leinster	4	28,57%
	Connacht	2	14,29%
Question 2	Which activities	14	
	Dairy	12	85,71%
	Dairy + Beef	2	14,29%
Question 3	Farm structure	13	
	1 labourer, between 25 and 50 dairy cows, between 25 and 50 ha (62-124 acres)	1	7,69%
	1 labourer, between 50 and 75 dairy cows, between 50 and 75 ha (124-185 acres)	2	15,38%
	1 labourer, more than 75 dairy cows, more than 75 ha (185 acres)	2	15,38%
	2 labourers, between 50 and 75 dairy cows, between 50 and 75 ha (124-185 acres)	1	7,69%
	2 labourers, more than 75 dairy cows, more than 75 ha (185 acres)	2	15,38%
	Other	5	38,46%
Question 4	Milk production (litres/dairy ha)	12	
	Average	17,625	
	Upper quartile	28,050	
	Lower quartile	8,550	

As previously stated, I collected data from 14 different farms. All these farms are in Ireland, but from different regions. We see most of these are from Munster, the same province where I did my placement. Each farm has a dairy production, 2 of them have a beef production in addition.

The average milk production per dairy hectare* is around 17,625 litres. (Dairy ha* = According to Teagasc eProfit Monitor, surface intended for the milk production or total farm without surface intended for the young-stock, crops, beef, etc.)

b) About the grassland

Question 5	Grassland size (dairy ha)	11	
	Average	196,7	
	Upper quartile	244,6	
	Lower quartile	105,2	
Question 6	Paddock system	13	13
	100% around the farm	6	46,15%
	Almost 100%, some paddocks are distant from the farm	3	23,08%
	More than 30% of the grassland are distant from the farm	4	30,77%
Question 7	Grass production (t MS/ha)	11	
	Average	12,4	
	Upper quartile	13,9	
	Lower quartile	10,4	
Question 8	Grazing system	13	13
	Strip grazing + Rotational grazing	8	61,54%
	Rotational grazing	4	30,77%
	Strip grazing	1	7,69%
Question 9	Grazing time	13	13
	12 hours	3	23,08%
	24 hours	4	30,77%
	36 hours	6	46,15%
Question 10	Average rotation length (days)	13	
	Average	20,7	
	Upper quartile	25,0	
	Lower quartile	16,2	
Question 11	Weekly workload for the grazing management (hours)	11	
	Average	12,0	
	Upper quartile	16,7	
	Lower quartile	2,1	
Question 12	The last major changes carried out to the grassland layout	13	13
	Last year	6	46,15%
	2 - 5 years ago	5	38,46%
	6 - 10 years ago	1	7,69%
	More than 10 years ago	1	7,69%
Question 13	Grassland layout satisfaction	13	13
	Very good	3	23,08%
	Good	3	23,08%
	Sufficient	6	46,15%
	Bad	0	0,00%
	Very bad	1	7,69%
Question 14	Frequency of the grass measuring	13	13
	Weekly farm walks	7	53,85%
	Sometimes	2	15,38%
	Never	4	30,77%

The average grassland size is almost 200 dairy hectares, and in 46% of cases the grassland is totally around the farm. The grass yield per hectare is around 12.4 tons dry matter, which means the average yield is rather low when we know the grass yield may be until 20 tons DM per hectare.

However, 2018 was very difficult year for grass production because the weather during the summer was very dry, there wasn't much rain from July to September. Therefore, the grass growth was considerably lower than every year end most of Irish farmers feel the winter 2018/19 will be difficult due to insufficient forage stocks.

About the grazing system used in the sample, there is one farmer who uses only the strip grazing, 4 farmers use the rotational grazing and finally 8 farmers use the strip grazing + rotational grazing. Indeed, most of the time the sizes of each field are different and it is difficult to match the herd to the field size, unless the grassland layout is redesign and therefore, remove ditches or make new roadways. However, if the farmer does not want to change his grassland layout, he can use the rotational and strip grazing in large field.

Moreover, the grazing time typically offered to the herd is 12 hours for 3 farms questioned, 24 hours for 4 farms and 36 hours for 6 farms. In average, a same field is grazed every 20 or 21 days (between April to August).

The average weekly workload associated with grazing management (setting up fences, grass measuring, fertiliser spreading, etc.) is 12 hours.

Most of the time, there were major changes carried out to the grassland layout these last years. 6 farmers are more than satisfied by their grassland layout, 6 rather satisfied and one farmer not satisfied at all by his grassland layout.

Finally, just over 50% of the farmers measure weekly grass production with plate meters for example. 15% do that sometimes and 31% never.

c) Economic data

Question 15	Gross output (€/dairy ha)	8
	Average	6205,0
	Upper quartile	7066,3
	Lower quartile	5360,0
Question 16	Variable cost (€/dairy ha)	8
	Average	1473,8
	Upper quartile	1540,0
	Lower quartile	1347,5
Question 17	Grass variable cost (€/dairy ha)	8
	Average	263,8
	Upper quartile	286,3
	Lower quartile	194,0
Question 18	Gross margin (€/dairy ha)	8
	Average	2618,8
	Upper quartile	3425,0
	Lower quartile	2087,5
Question 19	Net profit (€/dairy ha)	8
	Average	2356,3
	Upper quartile	2725,0
	Lower quartile	1775,0

The average gross financial output (sales + transfers +/- inventory) is €6,205.0 per dairy hectare, the variable cost (purchased concentrate/forage, fertiliser, lime, veterinary, breeding, contractor, seed, contractor, milk recording, etc.) is about €1,473.8 per dairy hectare, the variable cost bounds to the grass management (fertiliser, seed, etc.) is €263.8 per dairy hectare, the gross margin is €2,618.8 per dairy hectare and finally the average net profit is €2,356.3 per dairy hectare.

d) Social data

Question 20	Weekly workload (hours)	7	
	Average	65,7	
	Upper quartile	74,5	
	Lower quartile	57,8	
Question 21	Wish to decrease the workload	8	
	Yes, absolutely	3	37,50%
	Yes, but it is not the first aim	3	37,50%
	No	2	25,00%
Question 22	According to the farmer, cows fed with grazed grass is quality guarantee to consumers	8	
	Yes	8	100%
	No	0	0%

On average, Irish farmers, from the sample, work 65.7 hours per week. The upper quartile work more than 74.5 hours per week, in other words more than 10 hours per day. Conversely, the lower quartile work less than 57.8 hours per week that remains exceptionally high.

3 of these farmers absolutely wish to decrease their workload and 3 others wish this as well but it is not their primary objective. Finally, there are 2 farmers who do not care about their workload.

100% of farmers questioned believe that “cow grazed grass” is a quality guarantee to consumers.

e) Environment data

Question 23	Methods to preserve the farm environment	7	
	Increase hedge margin	4	57,14%
	Natural habitats	5	71,43%
	Bird boxes	1	14,29%
	Others set up	4	57,14%
Question 24	Fertiliser amount (kg N/dairy ha)	7	
	Average	156,0	
	Upper quartile	198,0	
	Lower quartile	138,0	
Question 25	Hedges (meters)	7	
	Average	8000,0	
	Upper quartile	10700,0	
	Lower quartile	3800,0	
Question 26	% of the grassland resow each year	8	
	0%	1	12,50%
	0 - 10%	4	50,00%
	10 - 25%	2	25,00%
	25-50%	1	12,50%
	More than 50%	0	0,00%
Question 27	Methods used for the grass reseeding	8	
	Ploughing	1	12,50%
	Direct drilling	1	12,50%
	Discing + sow	2	25,00%
	One-pass	4	50,00%

There are several methods to preserve the farm environment that is set up by the farmer. 57% of farmers questioned try to increase the hedge margin in order to maintain the wildlife biodiversity. 71% of them try preserving natural habitats as well. 14% builds bird boxes.

The average fertiliser amount is 156 kg of nitrogen per dairy hectare. The upper quartile spreads more than 198 kg N and the lower quartile spreads less than 138 kg N.

The average hedge length is around 8 km per farm.

One farmer does not reseed his grassland. 4 farmers reseed from 0 to 10% of their grassland each year, 2 farmers reseed from 10 to 25% of their grassland each year and 1 farmer reseeds from 25 to 50% of their grassland each year.

There are several methods for grass reseeding like ploughing (loosening the soil and burying surface elements such as weeds or residues from previous crops in the soil), direct drilling (the seed is placed without any prior soil cultivation in the stubble of the previous crop), discing (sowing after a shallow tillage) and one pass (seed sown using an air seeder attached to the power harrow). So, there is one farmer who uses ploughing, one farmer uses direct drilling, 2 farmers use discing and 4 farmers use one pass method.

f) Farmer's satisfaction

Question 28	Economic performance satisfaction	8	
	Very good	4	50,00%
	Good	1	12,50%
	Sufficient	2	25,00%
	Bad	1	12,50%
	Very bad	0	0,00%
Question 29	Social aspect satisfaction	8	
	Very good	2	25,00%
	Good	2	25,00%
	Sufficient	2	25,00%
	Bad	1	12,50%
	Very bad	1	12,50%
Question 30	Environment sustainability satisfaction	8	
	Very good	2	25,00%
	Good	3	37,50%
	Sufficient	1	12,50%
	Bad	1	12,50%
	Very bad	1	12,50%

At the end of the survey, there were several questions to know how the farmer evaluates his farm compared to the 3 dimensions of the sustainable development.

We can see Irish farmer are rather satisfied by the economic situation of their farm, there is only one farmer who evaluates his farm economic as bad.

About the social aspect, it is more shared because there are 2 farmers who think are not really satisfied by their social aspect within their farm.

Finally, most of famers are satisfied by the environment within their farms, although there are 2 farmers who are not really satisfied.

4. Discussion of results

According to the introduction, in order to get an answer for the question: "How can the farmer correspond his grazing system to his farm's challenges?" I decided to focus myself on 3 different sub-questions and particularly on three different dimensions of the sustainable development: Economic, social and environment.

Therefore, there were several questions in the survey related to these dimensions.

a) Economic perspectives

As it was said in the introduction, grazed grass is the cheapest food that the farmer can give for his herd. However, the farmer should try to improve the food cost even if feeding of his herd is already based on grazing.

As a reminder, the average gross financial output is €6,205.0 per dairy hectare, the variable cost is about €1,473.8 per dairy hectare, the variable cost bounds to the grass management is €263.8 per dairy hectare, the gross margin is €2,618.8 per dairy hectare and finally the average net profit is €2,356.3 per dairy hectare.

We can compare these data with the "*Teagasc Profit Monitor Analysis Dairy Farms 2017*" (Teagasc, 2017), which gathers the averages of technical, economic and financial performances of Irish dairy farms. By comparing annual differences, this allows us to understand how our farms are compared to the rest of Ireland:

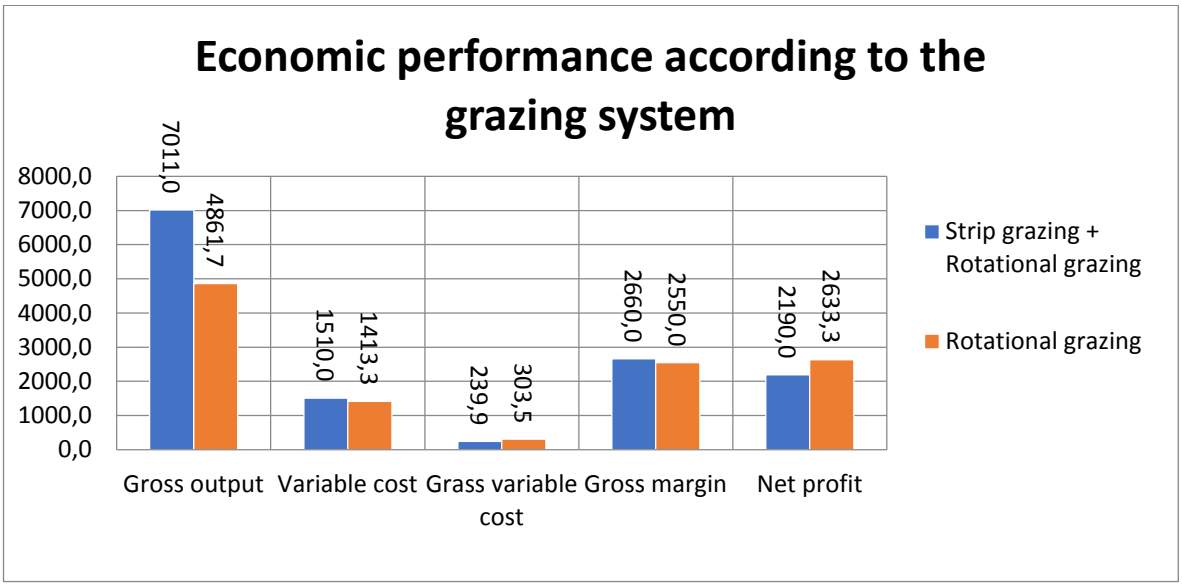
/dairy hectare	**Average from sample's farms**	***Teagasc Profit Monitor 2017****
Gross financial output	€6,205.0	€4,831
Variable cost	€1,473.8	€1,531
(Grass management)	*(€263.8)*	*(€287)*
Gross margin	€2,618.8	€3,304
Net profit	€2.356.3	€2,137

(Teagasc Profit Monitor 2017: Spring milk dairy farms; 1,568 farms)*

So, we can note the economic and financial situation of our farms is a bit more efficient than the average if we see only the net profit. This is explained in particular by the average gross output and variable costs are better in the case of the sample. But if we see that the average gross margin is lower than Teagasc.

As it mentioned earlier, the 2018's context was difficult for Irish farmers due to the dry weather unlike to 2017. So, it would be better to compare the *Teagasc Profit Monitor* from 2018, but when this report was written (end of 2018), this profit monitor was not available at that time.

Then, we could now compare farms between themselves, in order to know which one has the best economic situation and relative to the grass management. In the following chart, we can see average economic/financial performance between a strip grazing/rotational grazing system and a rotational grazing system:



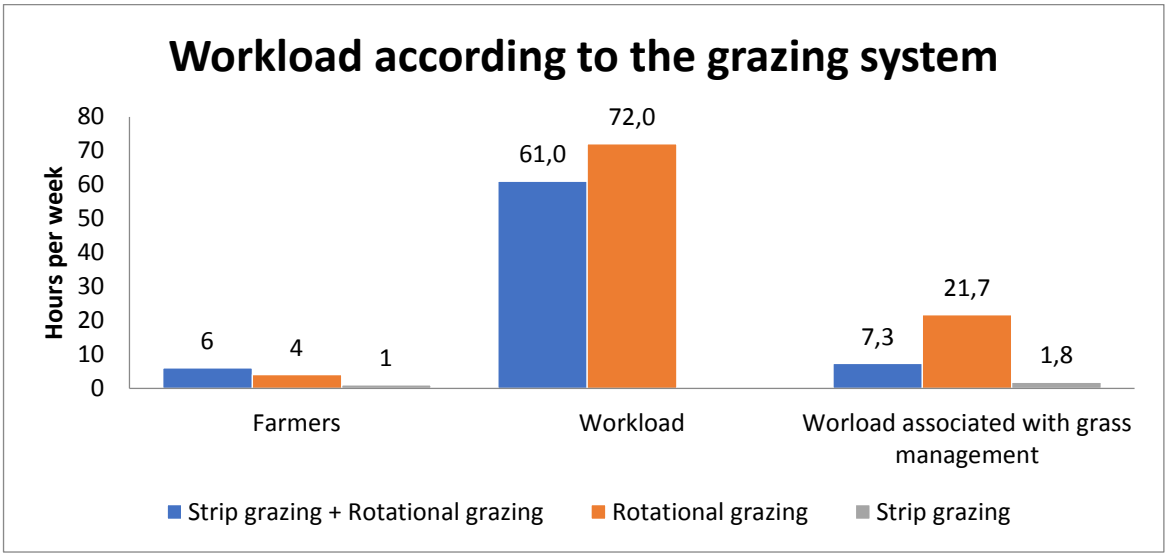
It is important to say there were only 8 farmers who filled in this part of the survey and among them, 5 farmers have a strip grazing/rotational grazing system and 3 farmers have a rotational grazing system. No farmers who have a strip grazing system filled in this part.

We can see with this graph farmers who have rotational grazing system are little bit more efficient when we look at the net profit per dairy hectare, despite their gross margin is less. In as much as the sample is narrow, it is difficult to make conclusion, but we can imagine farmers who use strip grazing / rotational grazing may have more amortizations/depreciation and interests, that could explain this difference between the gross margin and the net profit.

b) Social satisfaction

When we talk about the social satisfaction in agriculture, it means how the farmer is feeling according to the time spent with his family/friends so how heavy is the workload, but also how are relationships with the neighbourhood and especially with consumers.

The average weekly workload of our sample is 65.7 hours that may seem "normal" in agricultural world, but enormous if we compare with sectors of work. Among these 65.7 hours, around 12 hours are destined for the grazing management (setting up fences, grass measuring, fertiliser spreading, etc.). In the following chart we can see how the workload is allocated according to the grazing system used by the farmer:



So, at first glance, we see that the rotational grazing needs more time for the farmer than other grazing systems. However, it is necessary to relativize this tendency because the number of farmers per system is very heterogeneous. Indeed, there is only one farmer who uses strip grazing and replied to this question while there are 4 farmers who use rotational grazing and 6 farmers who use strip grazing/rotational grazing.

To end with the workload aspect, there are 37.5% of farmer questioned who would like absolutely to decrease their workload and another 37.5% who would like decrease the workload as well, nevertheless it is not their first aim. The last 25% consider their workload is correct and it is not an objective to decrease it.

We have only spoken about the workload until now and not about the relationship between the farmer and consumers. One of strengths of Irish milk production is most farms have a system based on grass. So, both farmers and distributors use an image of a cow in a field in order to show the "enormity" of Irish milk production. Anyway, 100% of farmers questioned approved of cows who are fed by grazing is a quality guarantee to consumers

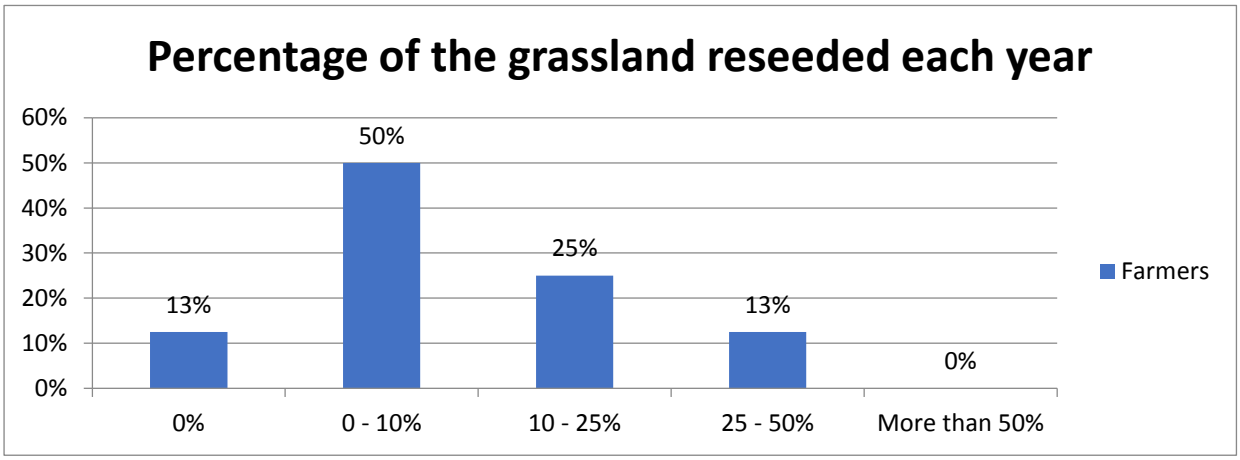
c) *Environmental protection*

Nowadays, the biggest problem in dairy production is the emission of greenhouse gases, especially methane gas. This gas is produced during digestion of organic matter, therefore by ruminants (monogastrics cannot or very little digest organic matter).

However, farming has the capacity to store carbon, especially through pastures and hedges. Indeed, if the plant produces carbon dioxide following cellular respiration, it will also store this carbon during photosynthesis. Photosynthesis takes place during the day in the presence of light and it allows transformation of atmospheric carbon into plant tissues when the plant is properly fed with nitrogen and other minerals. So, it is important to talk about the footprint and not just emissions.

However, as it was said previously, it is difficult to calculate this carbon footprint, because there are too many factors that must be taken in account. We can try to imagine that the more we stimulate grass growth (with rotational grazing/strip grazing rather than stock grazing for example) and we will see more carbon storage and therefore, improve the footprint.

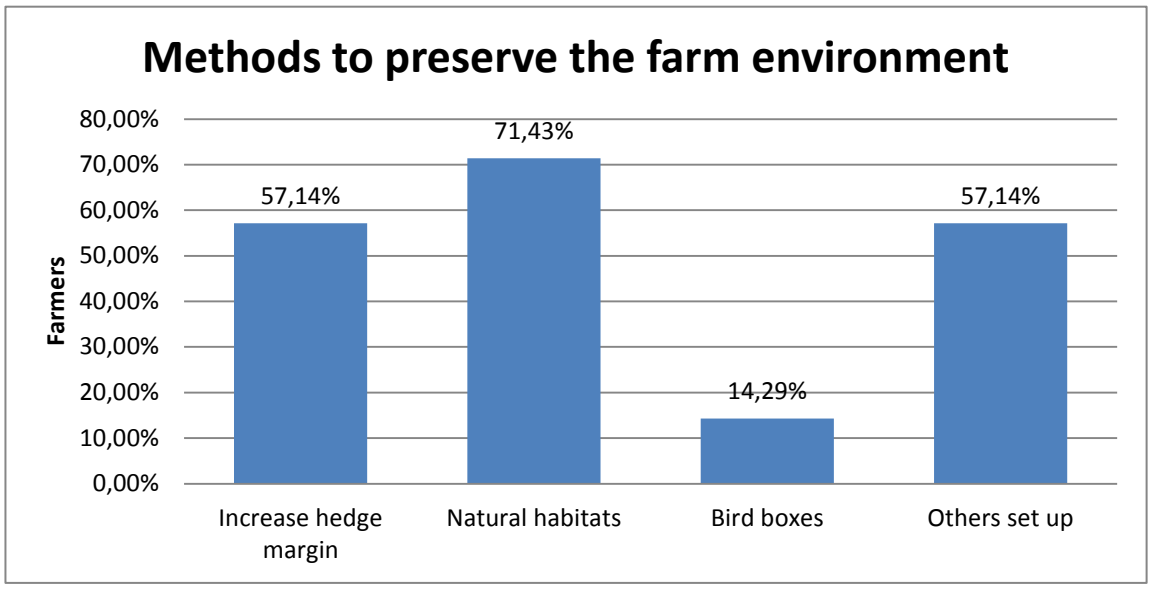
If carbon can be store in the plant and then in the soil (organic matter), this carbon can also go back to the atmosphere during ploughing in the form of carbon dioxide. In the survey, farmers were questioned about the percentage of the grassland reseeding each year.



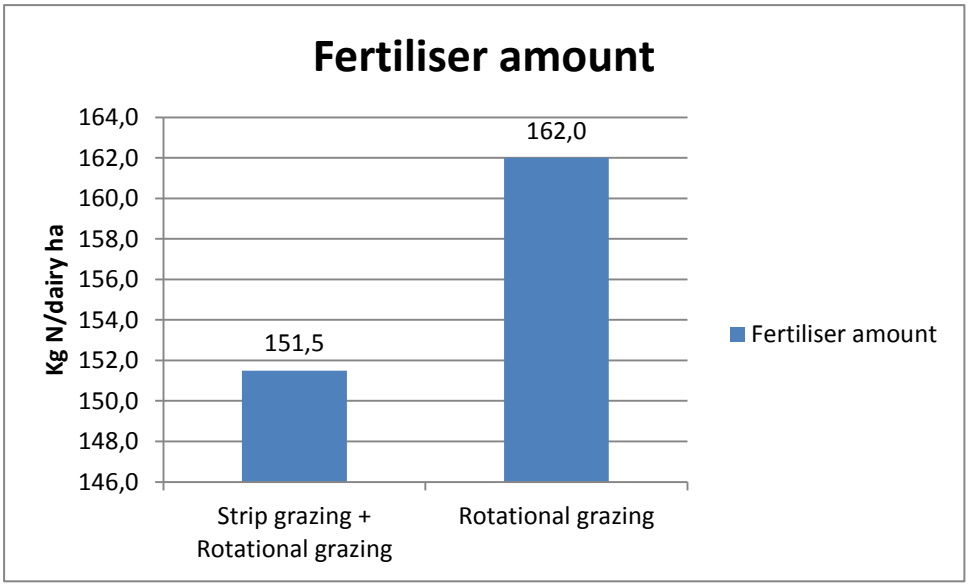
So, in this graphic, we can see that 13% of farmers questioned do not reseed their grassland. Then 50% who reseed less than 10% of their grassland each year, 25% reseed from 10 to 25% of their grassland each year and 13% reseed from 25 to 50% of their grassland each year.

There is a slight trend showed that farmers with a system like strip grazing and rotation every 12/24 hours reseed a larger part of their grassland. This is explained by the fact of the number of animals and the amount of grazing is more important, so ground is more prone to settlement and the plant density becomes lower after each graze. Therefore, the farmer must reseed more often, to work the soil, to release carbon dioxide…

There was a question where the farmer was asked if he had set up some methods to preserve the farm environment like increasing hedge margins (to support the biodiversity of the wildlife/flora) or put in place bird boxes. And if we see the following graph, we can see that all farmers questioned set up more or less these methods.



About the amount of fertiliser spreads per dairy hectare, we can see thank the following graph that the amount is higher in average for rotational grazing system. This is can be explained by the fact that if we use the strip grazing, we manage better the herd movement within the field and the scattering of dungs is more homogeneous. Therefore, there is a grass growth more regular and the need of fertilizer is less important.



To finish with the environment dimension, we can say that the grazing has an impact on the environment but it is difficult to choose one system more “eco-friendly” than another because a farmer who uses strip grazing and a rotation of 24 hours for example will be able to stimulate the grass growth and the photosynthesis as well as any other system. However the grassland renewal will be more

important so that a part of the carbon stored in the soil could join the atmosphere. Conversely, a system more extensive will store less carbon but this carbon will be more likely to stay in the ground in organic matter shape. Today, we can tell grazing management can have an impact on the carbon footprint and so the environment dimension, but there is not really an “ideal grazing system”.

It could be interesting to try to set up different systems of grazing on a same farm in order to compare the carbon footprint of each system. But it would take several years to analyze the values of database, and have the grassland and the herd suitable for this experiment.

5. Conclusion and recommendations

This thesis was written in order to know if grazing management could have an impact on the sustainability of a farm. Indeed, if the Irish dairy system is one of the most efficient in Europe today, there are several challenges that the Irish farmer has to cope with. For instance, the Brexit could have an impact on the Irish dairy export or Global Warming that could influence techniques and systems used by Irish farmers.

This thesis is also what will allow me to acquire my degree at the end of my studies. I participated in a placement for 14 weeks within an Irish company where I learnt more about the Irish agricultural system and met many farmers in order to share information and see how they run their farm, their futures, challenges and the agricultural world in Ireland. So, for me personally it was an excellent experience.

Today, milk production in Ireland has the particularity to be based on the grass. Indeed, the environment is exceptionally suitable to growing grass, so it is “easy” for farmers to produce milk cheaply. However, these farmers are faced with several challenges, especially Global Warming. Today the consumer expects the farmer to have a healthy product, that is not too expensive and of course eco-friendly.

Therefore, I chose to base my thesis about the consequences of grazing management on the sustainability of farming. When we hear “sustainability”, we generally make references to sustainable development, this means if the production is economically viable, socially livable and environmentally friendly.

Thanks the sample of 14 Irish farmers, it was possible to analyze several technical and economic performances, different grazing systems used, etc. However, 14 farmers is not a large sample, so conclusions established in this thesis must be taken with precaution.

Firstly, there was the economic aspect analysed. The trend showed farmers who have a rotational grazing system are more efficient because the average net profit per dairy hectare was better than those who used both strip/rotational grazing.

Secondly, we tried to compare the social dimension according to the grazing system set up. The average workload was about 60 hours per week that is a lot if we compare it with other sectors of work. Then, the workload for the grazing management was mainly more for farmers who used rotational grazing. However, the number of farmers for each grazing system was not really homogeneous, so the

trend has to be taken with caution. We can still say that Irish farmers, as in most countries, have a heavy workload.

Finally, there was the environment that was analysed. We can say that the milk production is certainly problematic because greenhouse gases emissions are rather important and therefore contribute to global warming. However, as it was said in the introduction, farmers are able to store greenhouse gases thanks pastures and hedges , so it is important to talk about “net carbon footprint”. We could imagine the situation where the footprint is improved by stimulating the grass growth (with a rotational grazing/strip grazing rather than the stock grazing for example) which in turn will store more carbon. Moreover, it is same for the fertiliser management, we saw that the grazing system used can have an impact on the fertiliser amount spread.

So, it is difficult to nominate which grazing system is the better for the farm sustainability, because if we focus on the economic dimension, the rotational grazing seems more efficient, but it needs more workload compared to the strip/rotational grazing. About the environment, each system has its advantages and disadvantages, but whatever the grazing system used, the grazing is benefic for the environment (carbon storage and maintaining biodiversity).

It is important to relativize because, first of all newspapers and social media run to find the most destructive emissions in reports on global warming, but lest we forget too often only agriculture is able to store part of its emissions, unlike industrial sector or transport for example. In addition, farms have many keys to reduce their carbon impacts and in parallel improve the economic situation of farms. Finally, it would be appreciated if society realizes that agriculture today is far from what it was in the 1970s for example. Indeed, challenges and techniques are not the same, but Irish farmers have the merit of producing high quality products, while having a desire to safeguard the environment.

As it was said before, it could be interesting to compare the carbon footprint from different grazing systems, trying to have an identical environment in order to have concrete results. In the case of my thesis, each of the farms were different other that they are all Irish, so it was difficult to get concrete trends. However, this thesis allows us to have a first approach and to develop study perspectives that could be set up in the coming years.

6. Annexes

a) Annexe n°1: Survey used for the data collect

Part 1: Farm presentation

- Where are you from?
- Which activities are present in your farm?
- Can you present your farm structure?
- Milk production (litres/dairy ha)

Part 2: Grassland presentation

- What is the grassland size? (dairy ha)
- Is your farm in a paddock system?
- Grass production on the farm? (average dry matter/hectare)
- What grazing system to you use?
- What grazing time do you typically offer the dairy herd?
- What is the average rotation length? (between April to August)
- What is the weekly workload associated with grazing management? Setting up fences, grass measuring, fertiliser spreading, etc
- When was the last major changes carried out to the grassland layout? (examples: new roadway system, paddock size, water system)
- Are you satisfied by your grassland layout?
- Do you currently measure your grass?

Part 3: Farm economic situation

- Gross financial output per hectare (€/dairy ha)
- Variable costs (€/dairy ha)
- Variable costs bound to the grass management (€/dairy ha)
- Gross margin (€/dairy ha)
- Net profit (€/dairy ha)

Part 4: Farm social situation

- On average , how much time do you work per week on the farm?
- Would you to decrease this workload
- In your opinion, is feeding your cows grazed grass a quality guarantee to consumers?

Part 5: Farm environmental situation

- Did you set up some methods to preserve the farm environment?
- What fertiliser amount do you spread? (kg N/ha)
- What is approximately the distance of hedges present in your grassland?
- What percentage of your grassland do you reseed each year?
- Which methods do you use for the grass reseeding?

Part 6: Farm evaluation

- On the scale of 1 to 10, how do you rate the economic performance of your system?
- On the scale of 1 to 10, how do you evaluate the social aspect your system? Conducive to having time with family, etc.
- On the scale of 1 to 10, how do you rate the environmental sustainability of your system?
- Any comments on the above questions?
- Are you interested to receive a copy of my thesis?
- If yes, let me your address

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