EIP-AGRI Focus Group

Grazing for carbon

STARTING PAPER

10 May 2017

Dr. ir. Agnes van den Pol-van Dasselaar MBA

funded by European Commission

Introduction

How to increase the soil carbon content from grazing systems? This is an intriguing and relevant question which can only be fully answered by combining knowledge from different disciplines. The H2020 EIP-ARI Focus Group "Grazing for carbon", consisting of 20 European stakeholders, will therefore work on this question in the period 2017-2018. The group will explore grazing management strategies, drivers and barriers for different grazing systems, and tools and business models to support successful grazing systems. The group will also identify research needs and ideas for EIP-AGRI Operational Groups. It will build on the outcomes of the Focus Group on Profitability of permanent grasslands and the Focus Group on Soil organic matter content in Mediterranean regions. The tasks of the Focus Group are explained in detail in Annex I.

Grazing, the interaction between plant and animal, is inextricably linked to agricultural grasslands. Agricultural grasslands are defined (Peeters *et al.*, 2014) as land devoted to the production of forage for harvest by grazing/browsing, cutting, or both, or used for other agricultural purposes such as renewable energy production. The vegetation can include grasses, grass-like plants, legumes and other forbs (herbaceous flowering plants that are not graminoid). Woody species may also be present. Grasslands can be temporary or permanent. Permanent grasslands are, according to EU definitions, grasslands that are five years or more under grass. Meadows are grasslands that are harvested predominantly by mowing; pastures are grasslands that are harvested predominantly by grazing.

Carbon can be naturally captured from the atmosphere through biological processes and stored in the soil for a long period of time. Grasslands absorb carbon dioxide during growth of the grass plants and store it in the different tissues. The majority of the aboveground biomass will be eaten by grazing animals and the carbon will eventually return to the soil as manure or to the atmosphere via enteric fermentation. The remaining grass and roots will eventually decompose and the carbon will be stored in the soil organic matter. Grazing has a direct impact on plant production and thereby on soil C inputs. It also influences the amount and composition of soil organic matter through its effects on litter accumulation and decomposition.

The potential of grasslands as a sink for carbon is enormous in Europe. The EU (28 countries) currently has a permanent grassland area of about 60 million ha (Eurostat, 2017). Permanent grasslands cover 33% of the total utilized agricultural area (see also Figure 1 on the next page). Plant litter and animal wastes continuously supply grassland soils, which generally contain substantial amounts of organic carbon. Grasslands store considerably more carbon in the soil organic matter than in the vegetation. Carbon sequestration brings additional carbon in the soil. A study on nine grasslands plots scattered over Europe displayed a net sink of grasslands for atmospheric CO_2 of -240 ± 70 g C m^{-2} year^{-1} (mean ± confidence interval at $p > 0.95$) (Soussana *et al.*, 2007). Grasslands could therefore potentially be a large contributor to mitigation of greenhouse gases, thus contribute to a solution to the global problem of climate change.

Grasslands are also vital for European agriculture. A large part of the grassland area is used as feed for ruminants, usually via grazing of cows, sheep and goats. Animal production is of major economic importance for many EU member states. Next to providing feed for animal production and next to carbon sequestration, grasslands deliver many other ecosystem services.

This starting document briefly describes the effects of grazing systems on soil carbon and the associated benefits of grasslands. It further describes some examples of tools and business models to improve the positive effects of grazing management. The purpose of this starting document is to serve as input for the first meeting of the Focus Group "Grazing for Carbon" mid-June 2017. In their meeting, the members of the Focus Group will discuss the question "how to increase the soil carbon content from grazing systems?"

funded by European Commission

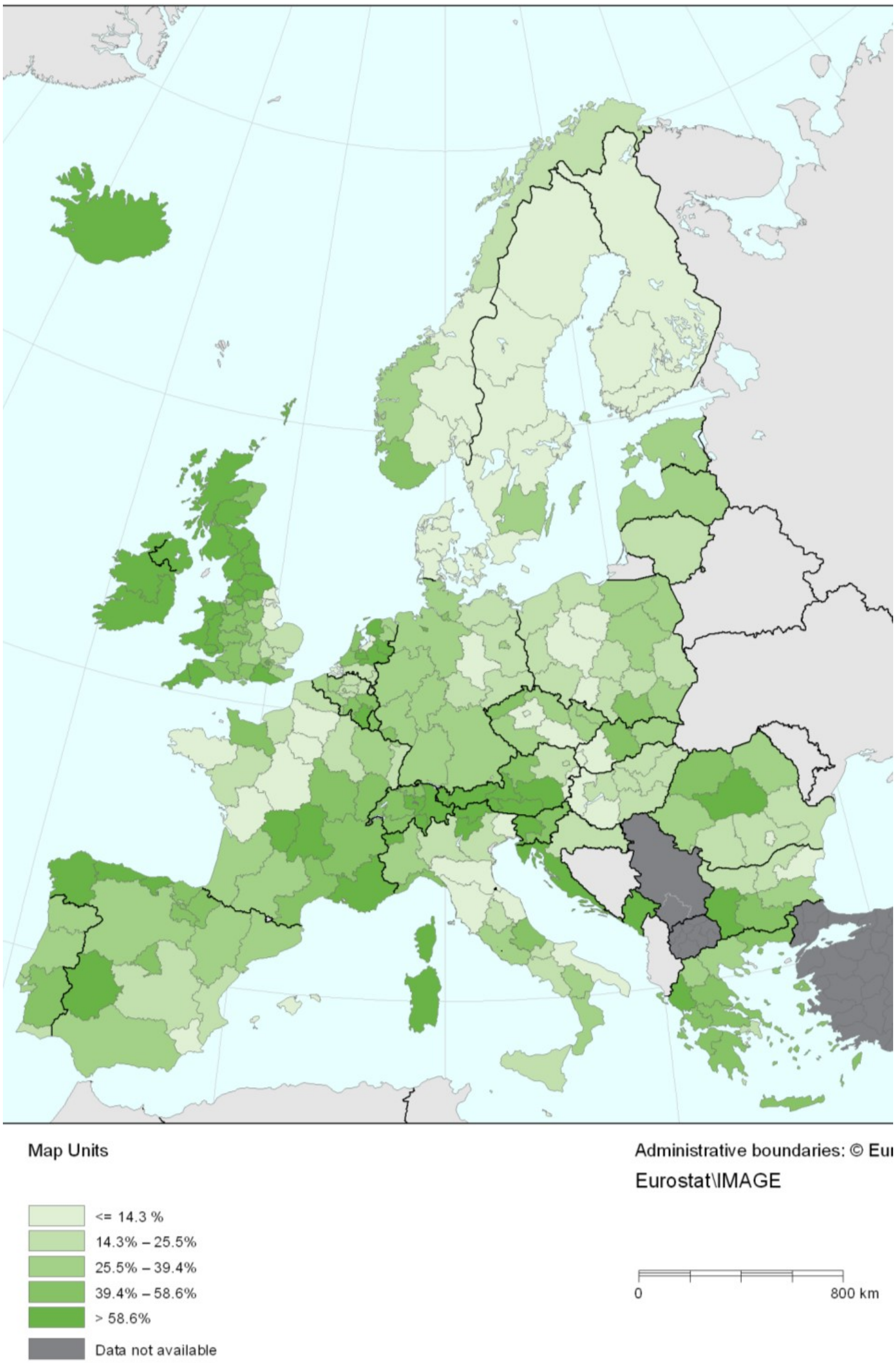

Figure 1. Share of permanent grasslands in the total utilised agricultural area in Europe in 2013 (source: Eurostat)

funded by European Commission

The role of grasslands in delivering carbon sequestration and other ecosystem services

Carbon sequestration

One of the roles of grasslands is that they act as a repository of carbon. Indeed, the world's soils are the largest terrestrial reservoir of carbon. So even when no additional carbon is sequestered, grasslands are very important in relation to climate change, since they store enormous amounts of carbon. Brogniez *et al.* (2015) created a map of the topsoil organic carbon content of Europe based on modelling (Figure 2). This map clearly shows the differences in organic carbon content between the North and South of Europe. The extent to which additional carbon can be taken out of the atmosphere by grasslands and stored in the soil will determine the overall role of grasslands in mitigating the impact of increased emissions.

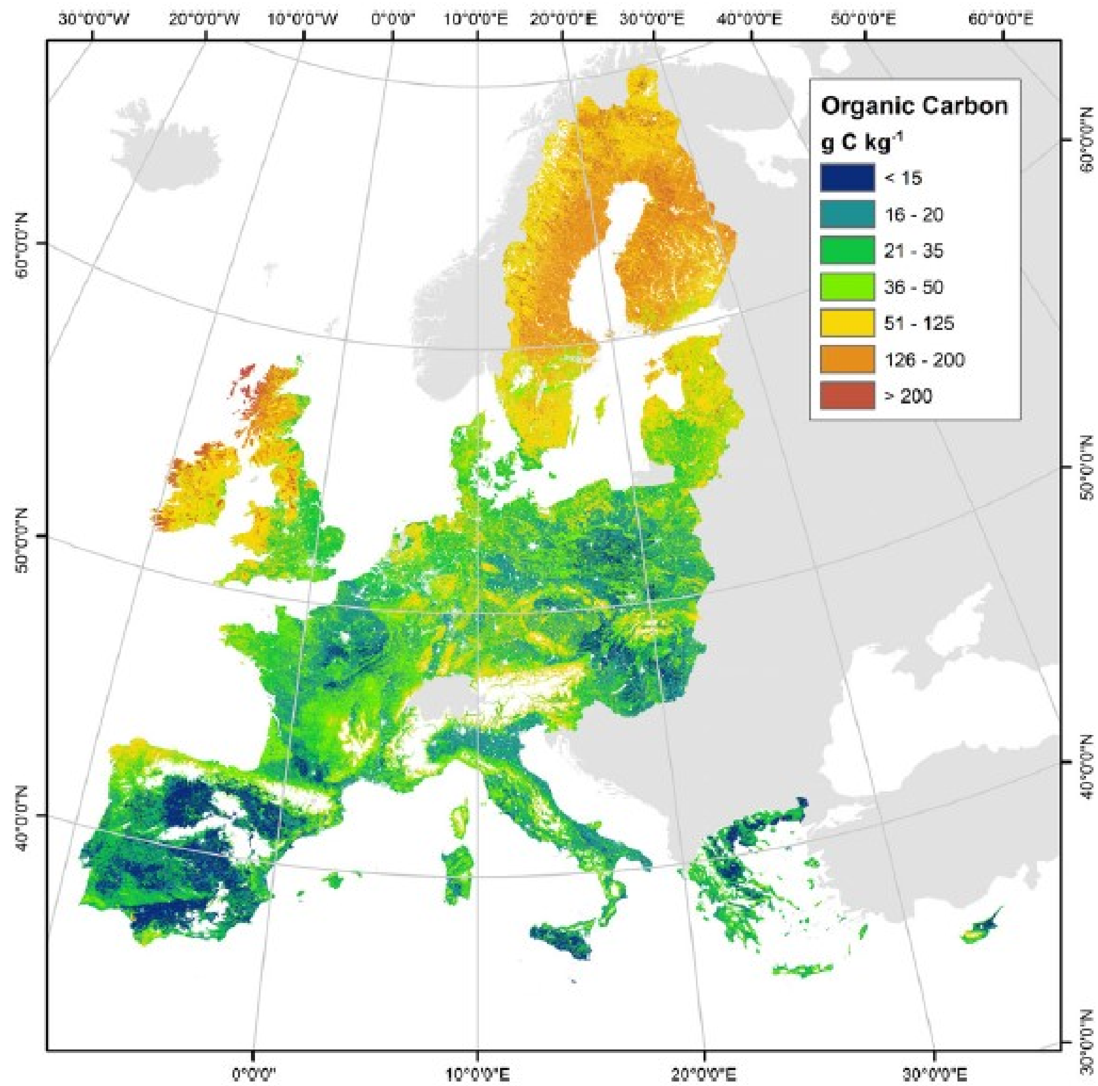

Figure 2. Map of predicted topsoil organic carbon content (g C kg^{-1}) (Brogniez *et al.*, 2015)

There is a lot of uncertainty with respect to carbon storage in soils and with respect to additional carbon sequestration. McSherry and Ritchie (2013) carried out a review on the effects of grazing on soil carbon in grasslands. They showed that different studies found both strong positive and negative grazing effects on soil organic carbon (SOC), that could only poorly be explained. McSherry and Ritchie performed a multifactorial meta-analysis of grazer effects on SOC density using variables soil texture, precipitation, grass type, grazing intensity, study duration, and sampling depth. They showed that grazer effects on SOC are highly context-specific which implies that grazers in different regions might be managed differently to help mitigate greenhouse gas emissions.

When grasslands are ploughed or when grasslands in wetlands become drier, grasslands typically loose soil organic matter and may turn from a sink into a source of carbon. This will of course affect the total amount of carbon stored in the soil. The C stock of grasslands will also be influenced by variations in climate (see Annex II for climate in Europe), soil types and management practices. Carbon sequestration is highly variable across small spatial scales. Another complicating factor with respect to carbon sequestration is the time scale. The process of sequestering carbon can take decades to centuries and the C sequestered as a consequence of a certain management strategy may be small in relation to the already present C stock of the soil. It is obviously difficult to detect relatively small changes in a huge pool of carbon. Therefore, it is difficult to find scientific evidence on C sequestration in field experiments which usually last only a limited period of time. This does not mean that the effect of management is not relevant. It certainly is, since the land area of grasslands is enormous and thus relatively small changes in C stock will have a huge overall effect. Modelling C sequestration in grasslands may help, but the results are depending on the quality of the data that are available as input. Jones (2010) showed that the potential for carbon sequestration in temperate grassland soils across Europe, ranged from 4.5 g C/m^2 /year (a C source) to 40 g C/m^2/year (a C sink). Jones combined data of field experiments and modelling results to come to his estimate. Although a great deal of work with respect to carbon in grasslands has been done in recent years, estimates of carbon storage and carbon sequestration in different ecosystems vary widely and more work is still required, e.g. on the differences between mowing and grazing which are still not completely understood.

Other ecosystem services of grasslands

Grasslands are known to deliver many other services and goods next to carbon sequestration. The concept 'ecosystem services' provides a good insight into the benefits that humankind gains from its interaction with natural resources, in this case with grasslands. The other ecosystem services of grasslands are relevant for the Focus Group, since they can be used as a promotor of carbon sequestration. The Millennium Ecosystem Assessment report (MEA, 2005) distinguishes four groups of ecosystem services: (i) provisioning services: products obtained from ecosystems, e.g. production of food, water, (ii) regulating services: benefits obtained from the regulation of ecosystem processes, e.g. control of climate and disease, (iii) cultural services: non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, e.g. recreation and beauty of the landscape, and (iv) supporting services: ecosystem services that are necessary for the production of all other ecosystem services, e.g. nutrient cycles, crop pollination.

The FP7 project Multisward (**www.multisward.eu**) aimed to get an insight into the importance of grasslands for stakeholders in Europe. For this purpose an on-line questionnaire was developed where the respondents were asked to value 42 different functions of grasslands. The respondents (n=1798) were asked to score for importance in their region (1 = not important; 5 = very important) (Van den Pol-van Dasselaar *et al.*, 2014). This stakeholder consultation clearly showed that there is a large number of different functions of grasslands that are highly recognized and appreciated. The function grazing had the highest average score of 4.2. Carbon sequestration, a regulating service, scored on average only a 3.3. The score for carbon sequestration varied between different regions of Europe and between different stakeholders. In general, policy makers gave the highest score. Farmers and industry gave the lowest score (Table 1). It is clear that an increased C storage is not seen as a positive effect by all stakeholders. Especially the relatively low value given by farmers is important to note, since the majority of measurements to increase the soil carbon content from grazing systems has to be carried out by farmers. Carbon sequestration is obviously not on top of mind of the farmers. Awareness by farmers is therefore an important issue.

funded by European Commission

Table 1. Importance of carbon sequestration in grasslands according to the respondents of a Multisward questionnaire (1 = not important; 5 = very important) (data are derived from Hopkins *et al.*, 2014) (*n.a.* = not available)

	Advice	Education	Farmers	Industry	NGO	Policy maker	Research	Students
Belgium	3.7	3.5	3.3	3.3	3.0	3.9	4.1	3.4
France	3.5	3.6	3.5	3.3	2.0	3.8	3.8	3.2
Ireland	3.0	3.1	2.8	2.3	4.0	3.9	3.3	3.3
Italy	3.6	3.6	2.9	3.0	3.3	3.3	3.2	3.0
The Netherlands	3.3	2.8	2.9	3.2	4.0	3.9	3.5	*n.a.*
Poland	2.5	3.1	2.7	2.2	2.3	*n.a.*	3.3	2.7

Grazing methods

There are many different grazing methods. The Focus Group Grazing for Carbon will look into alternative grazing management systems which can improve underlying economics and positive environmental effects, notably soil carbon storage. A large part of the European grasslands is grazed by cattle, beef and sheep, and the different grazing systems affect the soil C content. The extent of grazing for dairy cows has decreased in the last decade (EGF Working Group Grazing).
Allen *et al.* (20110) identified 20 grazing methods (or stocking methods as they prefer 'stocking' to 'grazing' (i.e. 'stocking method' vs. 'grazing method'). These grazing methods will be used as a start of the discussion in the Focus Group. An explanation of the different grazing methods can be found in Annex III.

- Alternate stocking
- Continuous stocking
- Creep stocking
- Deferred stocking
- First-last stocking
- Forward creep
- Frontal stocking
- Intensive early stocking
- Intermittent stocking
- Mixed stocking
- Mob stocking
- Non-selective stocking
- Put-and-take stocking
- Ration stocking
- Rotational stocking
- Seasonal stocking
- Sequence (sequential) stocking
- Set stocking
- Strip stocking
- Variable stocking

funded by European Commission

Management practises that affect the soil carbon content of grazing systems

How to increase the soil carbon content from grazing systems? A range of management practices to reduce C losses or to increase C sequestration has been addressed in research and practise. Both reduction of C losses and increased C sequestration are important, since it is the overall balance of C losses and C sequestration that determines the pool of stored carbon in the soil. The effect of many of these management practises is location-specific, i.e. the effect depends on the particular site. Different sites lead to different results due to differences in e.g. soil type, current soil C content, climate etc. The extent to which C can be taken out of the atmosphere by plants and stored in the soil is important in mitigating the impact of increased emissions.
A non-exhaustive list of measures related to grazing systems can be found below. This list needs to be extended and elaborated by the Focus Group, which is also the main task of the Focus Group. We are explicitly looking for cost-efficient and simple measures because they are most likely to be implemented.

Some examples of management practises that affect the soil carbon content of grazing systems:

- Soil tillage / length of grass periods
  - Avoid soil tillage, that leads to the break-down of organic matter and corresponding C losses
  - Avoid conversion of grasslands to arable cropping (or stimulate converting arable land to long-term permanent pastures, this option is however out of scope for the Focus Group)
  - Increase the duration of grass leys (short-term grasslands)
  - Convert grass leys to grass-legume mixtures or to permanent grasslands
- Fertilisation / minerals
  - Make nutrient poor grasslands more productive
  - Reduce N-fertilizer inputs in intensively managed grasslands
  - Liming
- Grazing practises
  - Different grazing methods
  - Different stocking rates (livestock unit/ha): intensive, extensive
  - Avoid overgrazing / use light grazing instead of heavy grazing
- Botanical composition / plant species
  - C_3 versus C_4 grasses[1]
  - Different C sequestration in different grass, legume and herb species

The effect of many of these practises is interrelated. For example, the optimum mixture of species will differ between regions and the effect of grazing can be different for different species[2].

When looking at grazing systems, it is important to look at the field level to the effect of grazing systems on the content and quality of humic substances in soils in different soil and climatic conditions. It is also important not only to look at the field level, but also at the farm level, since animals are involved in grazing. When looking at the greenhouse gas balance at farm level, animals contribute to greenhouse gas emissions via emitting CH_4 from rumen fermentation and by emitting CH_4 and N_2O from manure. The manure from the animals will also lead to increased grassland yields thereby contributing to enhanced storage of soil C.

---

[1] C_3 and C_4 refer to different photosynthetic processes. C_3 grasses are more common in temperate regions, C_4 grasses are more common in warm regions.

[2] McSherry and Ritchie (2013) found that an increasing grazing intensity increased soil organic carbon (SOC) by 6–7% on C_4-dominated and C_4–C_3 mixed grasslands, but decreased SOC by an average 18% in C_3-dominated grasslands.

funded by European Commission

Examples of successful grazing systems

Currently there are hardly any examples of undoubtedly successful grazing systems that combine a high C sequestration with other positive effects. The examples that are most outstanding often involve grasslands that have not been ploughed for decades or centuries but the area related to these grasslands is limited.
What we need to define as a Focus Group are current and innovative inspiring examples of grazing management systems for ruminants under different soils and various pedo-climatic conditions and management intensities (ranging from extensive to intensive), and their effect on soil C storage and other ecosystem services. We should have special focus on intensive production systems where the potential carbon sequestration is often under used, and areas under high pressure of climate change. These areas have often fragile ecosystems, where the removal of grazing practices would have negative consequences for the local and global environment (e.g. desertification). Although it delivers a number of ecosystem services, production in these areas is often not economically rewarding. An important aspect of inducing change is to find a way to ensure that people economically benefit. As already said, we are explicitly looking for cost-efficient and simple measures because they are most likely to be implemented. Furthermore, we need to get insight in the drivers and barriers to increase the soil C content from grazing systems.

Example: Mob-grazing is an intensive rotational grazing system, which is based on the idea of grazing a large amount of cattle on a small amount of land, for a very short period of time. It should lead to an uniform consumption of forage, an even distribution of urine and dung and higher C contents in the soil since the cattle trample the non-eaten plants into the soil. However, others claim that soil C content will decrease as a result of mob grazing

What are the drivers and barriers to increase the soil C content from grazing systems?

Potential drivers for grazing systems that increase the soil C content can be used to stimulate the implementation of these grazing systems. And actions can be defined to overcome potential barriers or constraints to implement grazing systems. Since the grazing systems usually have to be implemented by farmers, the drivers and barriers below are defined from the perspective of farmers. However, other stakeholders that may contribute to grazing systems, may experience other drivers and barriers since they are looking from a different background with a different point of view.

Drivers for farmers

The main driver for implementing grazing systems that increase the soil C content is the associated increased overall soil quality. An increased soil quality will lead to soils and plants that are more resilient, less susceptible to diseases, better adapted to dry and wet periods and, consequently, have a potentially higher production capacity. In the long-term this will lead to a more competitive farming system.

funded by European Commission

Barriers/constraints for farmers

There are also a number of barriers/constraints for implementing measures to increase carbon sequestration. Some important ones are:

- Unfamiliarity with the practise / lack of knowledge
- Uncertainty with respect to the effect of the practise, i.e. will it really lead to the expected benefits like increased soil C content and increased soil quality?
- Uncertainty whether the farmer will be able to implement the practise / lack of knowledge
- Risk of yield loss in the short-term
- Direct costs in the short-term
- Uncertainty about the cost-efficiency in the long-term
- Institutional barriers

Drivers and barriers can also be highlighted from the perspective of other stakeholders, e.g. policy makers or advisers. Policy makers might look at the issue from a territorial point of view or a more socio-economic point of view. Advisors usually see the same drivers and barriers as farmers. An additional barrier to many advisors is that they are not specialised in the topic grazing nor in C sequestration.

Tools to improve grazing management / tools to optimise C storage

Improved grazing management can be supported by management tools for farmers and advisors. There are currently a large number of tools available that support the farmers in their grazing management, e.g.

- Software, like decision support systems as Herb d'Avenir (Fr), PastureBase Ireland (Ire), Grip op Gras (NL)
- Hardware to measure grass growth and grass intake of grazing animals, e.g. many different plate meters to measure grass allowance and sensors for grass intake

There are also specific tools for the C cycle and greenhouse gas emissions at farm level, e.g.

- The Cool Farm Tool: **https://coolfarmtool.org/coolfarmtool/greenhouse-gases/**
- C-TOOL (Denmark): **http://gefionau.dk/c-tool/**
- The FarmAC model (developed in the FP7 project AnimalChange): **http://www.farmac.dk**

Specific tools to support farmers and advisors to improve grazing management and to increase soil C sequestration under permanent and temporary grasslands are hardly available. For grassland farmers, the effect of their management on carbon sequestration is often not clear and therefore not taken into account. Arable farmers are much more aware of the benefits of a high soil C content.

Business models

The above text shows the importance of carbon sequestration in grasslands and the enormous potentially beneficial impact of increasing carbon sequestration in grasslands. It also shows the uncertainty in reaching the objectives and it is clear that different stakeholders (e.g. policy makers, farmers, advisors, scientists) value the importance of carbon sequestration differently. Another risk for implementing best practises are the associated costs and potential loss of production in the short term. These risks may hamper the introduction of measures to stimulate C sequestration and may lead to hesitance of farmers to take the measures. In the end, it may hinder the acceptance of relevant measures. Therefore, we need business models that stimulate carbon sequestration. We need to find a way to make sure that the people that have to carry out the measures do benefit, either economically or in another way.

funded by European Commission

One model to ensure that management practises will be carried out, is to make it an obligation. Obligation implies that measures are enforced by law (local, national or European). Obligation in itself is not a business model and will not lead to economic benefits for the people that have to carry out the measures. It may lead to an increased C sequestration, but may also burden the farmers that have to carry out the measures.

Rather than an obligation, it is better to stimulate the practitioners, by identifying successful business models. A good business model will ensure a rapid introduction of measures in practise. One could think of:

- Introduction of carbon rights for grasslands (with corresponding carbon trade)
- Introduction of a premium (paid by governments and / or consumers)
- Introduction of local products with a label of "C sequestration" and a corresponding higher economic value on the market

These business models could be supported by e.g.:

- Knowledge transfer on the added value / benefits of associated ecosystem services
- Knowledge transfer on grazing management; further development of tools to support optimum grazing management

Conclusions

The potential of grasslands as a sink for carbon in Europe is enormous. There are, however, also a number of uncertainties related to the effect of grazing systems on C sequestration. What we need to define as a Focus Group are current and innovative inspiring grazing methods to increase C sequestration under various pedo-climatic conditions and management intensities. By combining knowledge from different disciplines, we will be able to provide answers on the question "*How to increase the soil carbon content from grazing systems?*". As Focus Group Grazing for carbon we will explore grazing management strategies, drivers and barriers for different grazing systems, and tools and business models to support successful grazing systems.

funded by European Commission

References

Allen VG, Batello C, Berretta EJ, Hodgson J, Kothmann M, Li X, McIvor J, Milne J, Morris C, Peeters A, Sanderson M, 2011. An international terminology for grazing lands and grazing animals. *Grass and Forage Science*, 66, 2–28.

De Brogniez D, Ballabio C, Stevens A, Jones RJA, Montanarella L, van Wesemael B, 2015. A map of the topsoil organic carbon content of Europe generated by a generalized additive model. *European Journal of Soil Science*, 66, 121–134.

Eurostat, 2017. http://ec.europa.eu/eurostat

Hopkins A, Collins RP, Fraser MD, King VR, Lloyd DC, Moorby JM, Robson (Eds), 2014. EGF at 50: the future of European Grasslands. *Grassland Science in Europe 19*, 897 pp.

Jones M. 2010. Potential for carbon sequestration in temperate grassland soils. *Integrated Crop Management* 11: 1-18.

McSherry ME, Ritchie ME, 2013. Effects of grazing on grassland soil carbon: a global review. *Global Change Biology* 19, 1347–1357.

MEA (2005) *Ecosystems and Human Well-being: Current State and Trends*, Volume 1. 901 pp.

Peeters A., Beaufoy G., Canals R.M., De Vliegher A., Huyghe C., Isselstein J., Jones G., Kessler W., Kirilov A., Mosquera-Losada M.R., Nilsdotter-Linde N., Parente G., Peyraud J.-L., Pickert J., Plantureux S., Porqueddu C., Rataj D., Stypinski P., Tonn B., van den Pol – van Dasselaar A., Vintu V. and Wilkins R.J., 2014. Grassland term definitions and classifications adapted to the diversity of European grassland-based systems. *Grassland Science in Europe* 19: 743-7450.

Soussana JF, Allard V, Pilegaard K, Ambus C, Campbell C, Ceschia E, Clifton-Brown J, Czobel S, Domingues R, Flechard C, Fuhrer J, Hensen A, Horvath L, Jones M, Kasper G, Martin C, Nagy Z, Neftel A, Raschi A, Baronti S, Rees RM, Skiba U, Stefani P, Manca G, Sutton M, Tuba Z and Valentini R, 2007. Full accounting of the greenhouse gas (CO_2, N_2O, CH_4) budget of nine European grassland sites. *Agriculture, Ecosystems and Environment* 121, 121–134.

Van den Pol-van Dasselaar A., P. Goliński, D. Hennessy, C. Huyghe, G. Parente, J.L. Peyraud (2014) *Évaluation des fonctions des prairies par les acteurs européen*. Fourrages 218: 141-146.

funded by European Commission

Annex I: Tasks of the EIP-AGRI Focus Group "Grazing for Carbon"

The Focus Group "Grazing for carbon" is expected to carry out the following main tasks:

- Explore grazing management practices from ruminants and their business models that have a beneficial impact on soil quality and more specific on the carbon content. Which examples can be found in the EU taking into account different regions, soil types and climate?
- Compare these different management practices taking into account cost-effectiveness, labour and knowledge intensity in relation to the soil quality, and more specific soil carbon content.
- How can these grazing management practices be adapted to other conditions?
- Analyse economic and technical factors that stimulate or limit the implementation of these grazing management practices and indicate how to address them exploring the role of innovation and knowledge exchange.
- Identify tools to improve grazing management, e.g. grass measurement, data recording, decision support systems.
- Identify innovative business models.
- Identify further research needs from practice, possible gaps in technical knowledge, and further research work to address them.
- Suggest innovative solutions and provide ideas for EIP-AGRI Operational Groups and other innovative projects.

funded by European Commission

Annex II: Climate in Europe

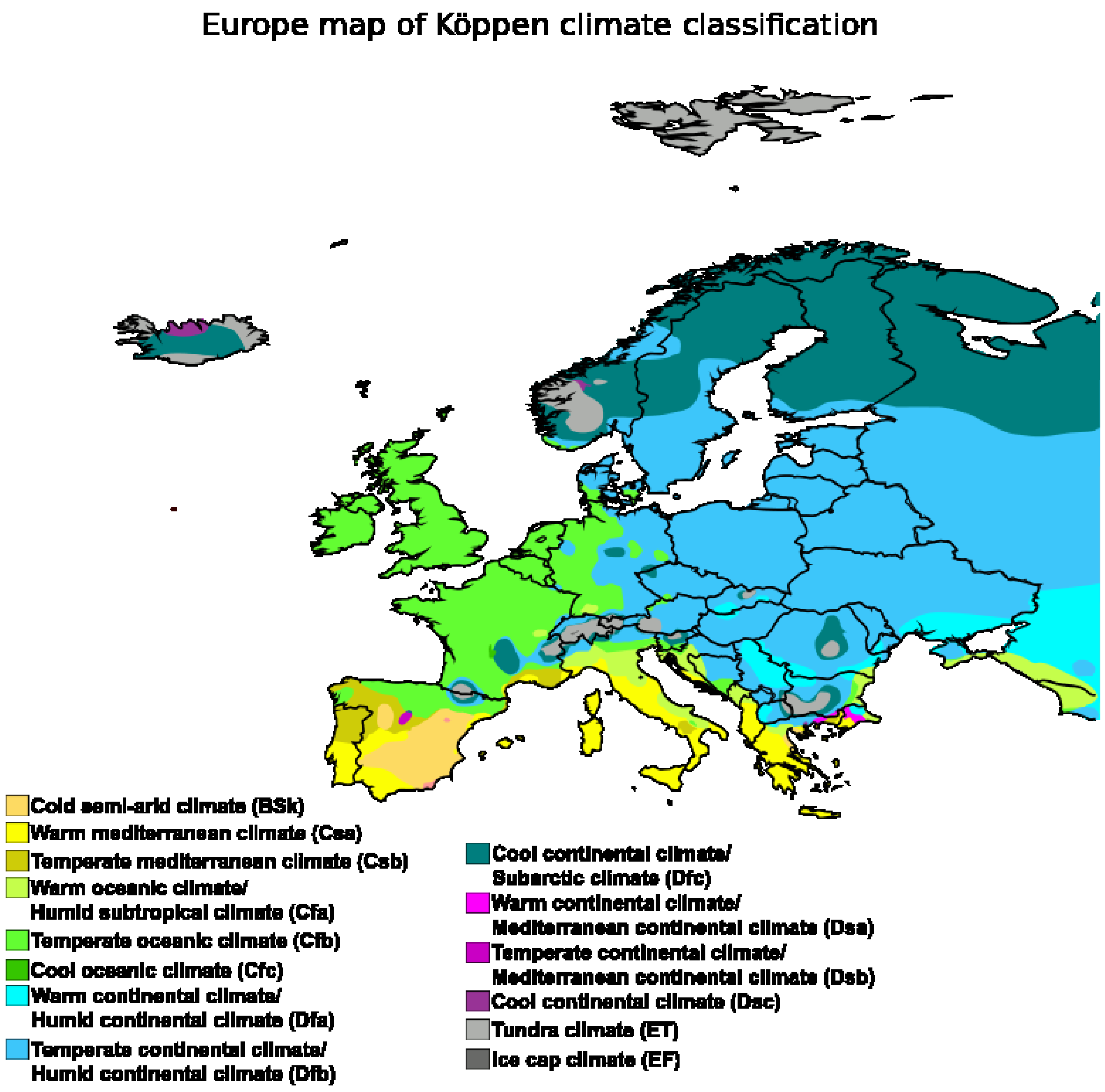

Figure 3. Climate in Europe.
(Source: https://commons.wikimedia.org/w/index.php?curid=47085770)

Annex III: Grazing methods, derived from Allen *et al.* (2011).

Note: According to Allen *et al.* (2011), the term 'stocking' is preferred to 'grazing' (i.e. 'stocking method' vs. 'grazing method') because grazing refers to the consumption of standing forage, whereas it is the method of stocking grazing animals that allows manipulation of how, when, what and how much the animals graze. While terms including 'Rotational grazing' and 'Creep grazing' are well established in the literature, the recommended terminology is 'Rotational stocking' and 'Creep stocking.' The alternative terms are included as synonyms in certain cases below. This section provides examples of stocking methods. This is not an all-inclusive list but provides examples of the more commonly used methods.

1 Alternate stocking. A method of repeated grazing and resting of forage using two paddocks in succession.

2 Continuous stocking. A method of grazing livestock on a specific unit of land where animals have unrestricted and uninterrupted access throughout the time when grazing is allowed (cf. Rotational stocking, 15; Set stocking, 18). Note: The length of the stocking period should be defined and in context with the rationale and season of use (Example: Grazing stockpiled forage from late autumn to late winter).

3 Creep stocking. A method to allocate unrestricted quantities of high-quality forage to maximize intake by juvenile animals while restricting forage intake to meet but not exceed the nutritional requirements of their dams (Syn. Creep grazing). Note: This method allows juvenile animals to graze in areas that their dams cannot access at the same time to optimize animal performance through highly selective grazing without competition from the dams.

4 Deferred stocking. A method to defer grazing on land units that may or may not be in a systematic rotation with other land units. Note: A key concept of deferred stocking is that the deferment is a conservation practice for restoring and maintaining the desired condition of the grazing land. It is not a practice to increase livestock production within a stocking season. However, along with other management strategies, such as reseeding, weed control and prescribed burning, deferred stocking can improve the response of desired vegetation and, over time, increase animal production potential.

5 First-last stocking. A method of utilizing two or more groups of animals, usually with different nutritional requirements, to graze sequentially on the same land area. Note: If more than two groups of animals graze sequentially, this would be described as 'first, second and last stocking.' The objective of this stocking method is to allocate nutrition among different groups of animals with different nutritional requirements such as lactating dairy cows and dry cows. Higher selective grazing and greater forage mass present during the period of occupation by lactating cows can contribute to meeting their higher nutrient requirements, compared with dry cows that are the second group to occupy the paddock. It may also include the objective of increasing total forage use such as grazing cattle or sheep as the second group of grazing animals behind horses as the first group (see Mixed stocking, 10).

6 Forward creep stocking. A method of creep stocking where dams and offspring rotate through a series of paddocks with offspring as first grazers and dams as last grazers. A specific form of First-last stocking (5). (Syn. Forward creep grazing).

7 Frontal stocking. A method that allocates forage within a land area by means of a sliding fence that livestock can advance to gain access to ungrazed forage.

8 Intensive early stocking. A method of using high grazing pressure during an initial restricted period of the stocking season followed by total removal of livestock for the remainder of the season to allow rest and recovery by the forage. Note: This method, designed for use with native rangelands dominated by warm-season species, provides a way to maximize use of forage during the early part of the stocking season when digestibility is generally highest and to overcome low forage digestibility during late summer.

9 Intermittent stocking. A method that imposes grazing on a particular management unit or area of land for indefinite periods at irregular intervals.

10 Mixed stocking. A method of stocking two or more species of grazing or browsing animals on the same land unit, not necessarily at the same time but within the same stocking season. Note: Objectives of mixed stocking include increased forage utilization, altering botanical composition, weed control and interruption of parasite cycles. Mixed stocking may be a form of first-last stocking where one animal species is followed by a second animal species with different grazing behaviour with the objective of increasing total forage use. In wildlife systems, many animal species can occupy the same land area either simultaneously or intermittently. Mixed stocking on rangelands is sometimes referred to as 'common use.'

11 Mob stocking. A method of stocking at a high grazing pressure for a short time to remove forage rapidly as a management strategy.

12 Non-selective stocking. A method that uses high grazing pressures that increase the consumption of less-preferred forage species by grazing animals (cf. Mob stocking, 11). Note: Non-selective stocking is generally attempted by using mob stocking with a high animal-to-forage ratio during short time periods. In practice, stocking to overcome preference is achieved rarely.

13 Put-and-take stocking. A method of using variable animal numbers during a stocking period or stocking season, with a periodic adjustment in animal numbers in an attempt to maintain desired management criteria, e.g., a desired quantity of forage, degree of defoliation, or grazing pressure.

14 Ration stocking. A method of confining animals to an area of grazing land to provide the daily allowance of forage animal^{-1} (cf. Strip stocking, 19; Syn. Ration grazing).

15 Rotational stocking. A method that utilizes recurring periods of grazing and rest among three or more paddocks in a grazing management unit throughout the time when grazing is allowed (cf. Continuous stocking, 2). Note: The lengths of the grazing and rest periods should be defined. Words such as 'controlled' or 'intensive' are sometimes used in an attempt to describe the degree of grazing management applied to this stocking method. These words are not synonyms for rotational stocking.

16 Seasonal stocking. A method to restrict use of a land unit(s) to one or more specific seasons of the year.

17 Sequence (sequential) stocking. The grazing of two or more land units in succession that differ in forage species composition. Note: Sequence stocking takes advantage of differences among forage species and species combinations, grown in separate areas for management purposes, to extend stocking seasons to enhance forage quality and / or quantity or to achieve some other management objective.

18 Set stocking. A method that allows a specific, non-variable number of animals on a specific, nonvariable area of land during the time when grazing is allowed (cf. Variable stocking, 20).

19 Strip stocking. A method that confines animals to an area of grazing land to be grazed in a relatively short time, where the paddock size is varied to allow access to a specific land area (cf. Ration stocking, 14; Syn. Strip grazing). Note: Strip stocking and ration stocking may or may not be a form of rotational stocking, depending on whether or not specific paddocks are utilized for recurring periods of grazing and rest (cf. Rotational stocking, 15).

funded by European Commission

20 Variable stocking. The practice of allowing a variable number of animals on a fixed area of land during the time when grazing is allowed (cf. Set stocking, 18)

funded by European Commission