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Shades of Greening: Reviewing the Impact of the new EU Agricultural Policy on Ecosystem Services

Abstract: In December 2013, the EU Agriculture and Fisheries Council formally adopted the new regulations for the reformed Common Agricultural Policy (2014-2020). The new regulations include three obligatory greening measures: ecological focus areas, maintaining permanent grassland, and crop diversification. We assess the impact of these measures on ecosystem services using scientific and gray literature. The literature review reveals that the adopted greening measures will have mixed effects, i.e., trade-offs and synergies across ecosystems services. Provisioning services, in particular crop production, are expected to decrease when the measures are implemented. All other service categories, i.e., regulating and cultural services, will increase – or are at least will not obviously be negatively affected – once the measures are implemented. However, in terms of trade-offs and synergies, much depends on objectives being pursued, the baseline or alternative land use underlying the comparison, and on the prevalent farming systems and farm characteristics. Including the ecosystem services concept into the design and assessment of policies would allow a systematic review of the consequences of measures also for services otherwise easily ignored.

Keywords: CAP, Greening, Environmental Services, Impact Assessment, Preferences, Ecological Focus Areas, Maintaining Permanent Grassland, Crop Diversification

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1 Introduction

Undoubtedly, the EU Common Agricultural Policy (CAP) is the most important agricultural policy mechanism that exerts influence on agricultural landscapes and the rural environment throughout the EU [1]. Various forms of payments remunerating farmers for fostering the provision of ecological services of agriculture have already been part of the CAP for a long time [2]. Yet, these payments have largely failed to address the extent of environmental degradation, in particular with respect to soil and water quality as well as biodiversity, resulting from agricultural practices [3]. Research on the reasons for failure has been conducted before. Reasons found are, for example, the restricted uptake of voluntary measures by farmers, the very limited budget assigned to such measures, and the poor adaptation to local ecological, economic, and cultural conditions [4-6]. Measures and premium levels are mostly determined uniformly at the level of Member States or other above-local levels. The cross compliance mechanism that was introduced in the CAP reform of 2003 is another prominent policy instrument aiming at, among others, preserving nature in agricultural landscapes. It links direct income payments to farmers' compliance with basic legal requirements concerning the environment, animal welfare, food safety, plant and animal health as well as to the requirement of maintaining farm land in a good agricultural and environmental condition (GAEC). Cross compliance has been criticized for being not overly targeted and for hardly going beyond what is already decided in the respective national or EU-wide regulatory or legal frameworks. Yet, it can be argued that it provides a powerful sanctioning mechanism that increases compliance with environmental regulations, thus, making them more effective. Further, national standards of GAEC of land use become more important with the introduction of cross compliance as they are considered to be part of the legal requirements that have to be met by farmers [7].

As an attempt to tackle the environmental challenges in the agricultural context more cost-effectively – and in a sense as some kind of upgrade of existing agri-environmental schemes and the cross compliance mechanism –, so called greening practices have been discussed and were recently adopted as an important element of the future CAP from 2014 onwards [8]. The greening practices include the obligation to adhere to certain environmental measures defined at EU level and going beyond the requirements of cross compliance. Otherwise 30% of the direct payments to farmers are cut. The three concrete measures farmers must adopt are a) ecological focus areas, b) maintaining permanent grassland, and c) crop diversification [8]. Since these compulsory measures will affect not only farmers implementing agri-environmental measures, but all farmers requesting direct support, there will be a massive increase in agricultural land where these measures are practiced. This in turn can be expected to have considerable impact on the rural environment throughout the EU.

However, in the course of the reform discussions in the past years, there has been a lively – and partly controversial debate – among academics and practitioners about the ecological effectiveness – and also the economic cost-effectiveness – of the suggested greening practices. Here, discussions circle mainly around the concrete design of the measures (e.g., what exactly does 'permanent' grassland mean?; what should be the minimum width of buffer strips?), the actual agricultural area that will be affected, the question if the designated minimum requirements in terms of size (e.g., 5% of arable land as ecological focus area) is sufficient; and, of course, if the envisaged budget share of 30% is adequate to achieve the objectives of a greener agricultural production in the EU [9,10]. Doubting the actual ecological contribution of the proposed measures, some authors accuse proponents of this reform to 'green wash' (i.e., legitimize direct payments) rather than to implement a 'true' greening of the CAP [11].

While the effect of CAP measures on environmental good and services have been researched before, we think a more differentiated and thorough analysis of the concrete effects of individual measures on the provision of various ecosystem services (ESS) prevalent in agricultural landscapes is missing [12-14]. Apart from provisioning services like agricultural products, agriculture-related ESS include pollination of agricultural crops, natural pest regulation, provision of water, soil, genetic diversity, climate and air regulation, but also cultural ESS such as landscape aesthetics [15]. While the aggregate effect of the CAP measures on ESS provision might be positive, it is highly likely that there will be trade-offs between ESS affected by these measures depending much on the detailed design of a respective measure as well as on the regional context it is applied in [16]. As pointed out earlier by Hauck *et al.* [17], the ESS framework offers the potential to systematically assess the impact of policies such as the 'greening of direct payments' on ESS based on evidence presented in scientific literature and other methods. In this paper, we make a first attempt of such an assessment of ESS.

We have reviewed existing literature to assess the potential impact of the above mentioned adopted greening measures. The review approach is laid out below, followed by the results, a discussion and conclusions. While the greening measures will certainly impact biodiversity, too, we did not look at impacts on biodiversity as our focus was on ESS.

2 Methods

While there is a vast body of literature on ESS, systematic reviews of policy impacts on ESS, published in scientific journals, are rare. Though the Web of Science (WoS) or Scopus are the most recognized proprietary databases for peer reviewed journal content [e.g., 18], they refer to peer-reviewed information only. Against this, Google Scholar also refers gray literature, such as the technical report by the European Environmental Agency [19] on green infrastructure or the report by Hart and Baldock [20] of the Institute for European Environmental Policy looking at the greening option of the CAP. For this reason, we chose Google Scholar over WoS and Scopus as our main database for the literature review. Nevertheless, we cross-checked the retrieved publication lists from Google Scholar with WoS and Scopus and included relevant publications that had not been revealed by Google Scholar. In total, we analyzed 67 publications, of which 55 publications were peer reviewed and 12 stemming from gray literature. A slight majority of publications (n = 36) had an EU scope, whereas the rest had a non-EU context.

We selected a number of common ESS based on the TEEB (The Economics of Ecosystems and Biodiversity) classification [21] and started our review using the keywords "ecosystem services" and the official name of the measure (e.g., "ecosystem services" and "ecological focus areas"). This, however, did not yield much information and we decided to use combinations of the name of the measure and a particular ecosystem service as many individual services are well studied, like erosion control or carbon sequestration. ESS researched were: Biomass for energy & biofuels, food production, livestock production, climate regulation, regulation of water flows, water purification, erosion control and prevention, pollination, pest control, recreation, and aesthetic information.

While information was much richer using this approach, we also realized that the terms ecological focus area as well as crop diversification are rather imprecise and a systematic review was not possible without further specifying the measures as explained in the following.

3 Impact of greening measures on ecosystem services

3.1 Ecological focus areas

Ecological focus areas are a fixed percentage of the farm land put to an environmental use rather than agricultural production. According to Hart and Baldock [20], the areas could include set aside (land with no productive purpose), unploughed land, buffer strips, flower strips, beetle banks, skylark plots, grass margins, maintenance of landscape features (including hedges, walls, terraces, ponds, and groups of trees), and even permanent crops managed with no or minimal inputs. According to the explanation of the main elements of the CAP reform [6], the reform foresees “ensuring an ‘ecological focus area’ of at least 5% of the arable area of the holding for most farms with an arable area larger than 15 ha – i.e. field margins, hedges, trees, fallow land, landscape features, biotopes, buffer strips, and afforested area. This figure may rise to 7% after a Commission report in 2017 and subject to a legislative proposal”.

In the following the measures: (a) set aside and (b) buffer strips are discussed separately concerning their impact on the provision of ESS (Table 1).

3.1.1 Set aside

The set aside of land in arable rotations has been a traditional practice across Europe for much of its agrarian history. Rotating crops and leaving land uncropped has a range of agronomic benefits including weed control, disease prevention, and improved soil fertility for future cropping [22]. Due to agricultural intensification, however, traditional set aside has decreased. In 1988, set aside was re-introduced as a voluntary and in 1992 as an obligatory supply control mechanism within EU agricultural regulations. While the primary aim of the policy was to control the supply of agricultural production, a bigger role for set aside in relation to environmental protection was recognized in the 2003 CAP reform.

Table 1: Summary of the impacts of different greening options of the CAP on ecosystem services. A + indicates a positive impact of the measure on the service. A – indicates a negative consequence on the services and a **ó** indicates mixed impacts. (For fields that are left blank the systematic review did not reveal insights.)

Ecosystem services	Ecological focus areas – set aside	Ecological focus areas – buffer strips	Maintenance of permanent grassland – intensive use	Maintenance of permanent grassland – extensive use	Crop diversification
Provisioning services					
Biomass for energy & biofuels	ó	ó	-	-	ó
Food crop production	-	-	-	-	
Livestock		ó	+	+	
Regulating services					
Climate regulation	+		-	+	+
Regulation of water flows	+	+	-	+	
Water purification	ó	+	-	+	ó
Erosion control and prevention	ó	+	-		+
Pollination	+	+	-	+	+
Pest control	-	ó			+
Cultural services					
Recreation		+	-	+	
Aesthetic information	ó	+	-	+	+

The effects of set aside on ESS depend on a variety of factors [22,23]:

1. whether set aside is rotational, i.e., if it forms part of a crop rotation system and moves around a holding over time, or whether it is non-rotational and remains in one place. For non-rotational set aside the duration of the set aside (short term, long term, or permanent) is important.
2. whether set aside land remains bare or has a vegetation cover. Differences in environmental impact also arise from different vegetation covers, including, for example, natural regeneration, stubble, or sown. The type of vegetation sown does make a difference, too (e.g., legumes vs. oil seeds).
3. the way, in which set aside is managed, for example, if herbicides are used to control weeds or if vegetation is cut.
4. site-specific conditions (like area and steepness of slopes) and more generally the environmental and climatic conditions of the areas, in which set aside plots are located, including the kind of vegetation surrounding it.
5. the history of use and management of the area.

3.1.1.1 Provisioning services

In the past EU CAP funding period (2008-2013), set aside has been used for the production of non-food crops, such as biofuels, biomass for energy production, pharmaceuticals, and industrial lubricants [22]. Silcock and Lovegrove [24] found that nearly six million ha of set aside in Europe is used for growing non-food crops. For example, in 2005, non-food crops on set-aside land accounted for 26% of total set-aside in France and 33% in Germany compared with just 14% in the UK [24]. The majority of EU countries increased their use of set aside for non-food crops, thus impede good environmental and agricultural practices, like fallow land [25]. Thereby, the vast majority of industrial crops grown on set aside are energy crops, in particular oil seed rape used for biodiesel, and to a lesser extent, short rotation coppice (SRC) and miscanthus [24]. While at least some energy crops need lower inputs in terms of fertilizers, pesticides, and fossil fuel powered field operations [24], they can have greater water requirements [26]. Another concern associated with energy crops is their possibly adverse landscape impact. This relates to their height and unfamiliar appearance (e.g., miscanthus), but also landscape diversity may be reduced by producing extensive monocultures of energy crops [27].

While a set aside period might be beneficial for future production, there is a clear trade-off between current production and set aside, as it is per definition land with no productive purpose related to food crop production.

3.1.1.2 Regulating services

In terms of climate regulation, set aside plays a role in soil carbon sequestration. The removal of atmospheric CO_2 by plants and the storage of fixed carbon as soil organic matter is increased by the conversion from conventional agriculture to land uses with high carbon inputs and low levels of disturbance, such as permanent set aside [22].

The main benefit set aside brings to water quality is the reduction of inputs, such as fertilizers or pesticides, to farmland and consequently a reduced pollution [24,28]. Set aside can also influence the ecosystems capacity to purify water, for example, via a reduction of leaching. However, Froment *et al.* [29] found that uncovered, bare fallow and natural regeneration appear to increase leaching risk of nitrate as there is no root zone that can keep soil mineral nitrate. Keeping an adequate soil cover and crop mix is hence a key factor for retaining the beneficial effects of set aside [23,30]. Laurent and Ruelland [31] analyzed the effect of catch crops, like Lopsided oat (Avena strigosa), on their capacity to reduce nitrate loads. The authors found that the efficiency of these crops is high as they can reduce the nitrate load between 20% and 70%. The regulation of water flows depends likewise on the soil cover. Naturally, infiltration rates are higher in areas covered by grass lands as opposed to bare soil [32]. Van Rompaey *et al.* [33] showed that the average soil erosion rate of the remaining arable fields is lowered when set aside is introduced. This is due to the fact that farmers tend to take out the steepest fields of production. However, similar to water purification, soil protection largely depends on management and more precisely on the presence and type of green cover [23]. The greatest erosion benefits are provided by non-rotational grass cover [34]. Again, bare soil is considered to have the highest negative effect on soil erosion [e.g., 35].

Set aside areas have a positive effect on bee abundance and pollination services [36]. If the location of honey bee colonies is close to flowering set aside areas, the weight and the brood area of these colonies are bigger than comparable colonies without access to set aside areas [37]. Grasslands rich in flowers offer suitable sites to host populations of wild pollinator insects, such as solitary bees, bumblebees, or hoverflies [38]. In terms of pest control, Liu *et al.* [39] found that poorly maintained or with green manure planted, but overgrown set aside areas can negatively impact surrounding farmland.

As an example, such set aside areas can become havens for rats and other pests, which infest neighboring properties, reducing overall farm productivity in the region.

3.1.1.3 Cultural services

In terms of cultural services, set aside can be seen as introducing diversity into arable landscapes and improving its amenity value. It can also introduce color into landscapes, for example through flowers such as poppies and butterflies in species-rich field margins or naturally regenerating wildflower grassland [24,40]. Yet, some citizens may feel that uncropped areas let the landscape appear untidy and unattractive, or disturb the more uniform appearance of surrounding land. In total, across Europe, the impact of set aside on the landscape, concerning its aesthetic value, was assessed to be neutral [34].

3.1.2 Buffer strips

Vegetated buffers have many forms and sizes, their breadth ranging from 0.5 m to 50 m or more, when, for example, including floodplains. Vegetation ranges from natural, semi-natural, to cash crops and includes grass strips, wildflower strips, strips sown to bird cover crops, unsown cultivated strips with naturally regenerated flora, sterile strips maintained by cultivation or herbicides, buffer strips, beetle banks, and even trees [41-43]. Their functions vary widely and change over time. For example, field margins had in the past – and often still have – practical farm management functions, such as hedges and walls, which were maintained to keep livestock in or out. Field margins also delineate the field edge and land ownership [41].

3.1.2.1 Provisioning services

Agroforestry buffers can be used for a number of provisioning services, and not only for the production of harvestable trees or shrubs grown among or around crops [e.g., 42,43]. Gopalakrishnan *et al.* [44] pointed at the use of riparian and roadway buffer strips to produce non-food products in form of biomass for energy or biofuel production. According to McCracken *et al.* [45], more open vegetation can be used for low-intensity grazing. Stutter *et al.* [46] and Lovell and Sullivan [47], however, recommended avoiding the use of buffer strips for 'fencing' livestock since, for example, the soil compaction due to animal intensive grazing will disturb the effectiveness of the strips as sediment sinks.

3.1.2.2 Regulating services

Similar to wetlands, buffer strips are currently under evaluation, amongst others, in the context of the 'Blueprint to Safeguard Europe's Water' [48] on their benefits for natural water retention, i.e., the services buffer strips provide in terms of regulating water flows. Water purification services are enhanced via permanent vegetated buffers, including vegetative filter strips, riparian buffers, and grassed waterways [14,49]. Buffer strips especially reduce the water pollution of nonpoint source water from agricultural land [50]. They exist in many areas to filter sediments from retained waters and deter sediment transport to water bodies and ground water. Along with reducing sediment transport, the filters also help to trap sediment bound nutrients as well as pollutants, such as pesticides [31,41,51,52]. In their synthesis of 80 representative experiments, Liu *et al.* [39] found a 10 m buffer and a 9% slope as optimizing the sediment trapping capability of vegetated buffers. The trapped pollutants are absorbed by the plants and broken down by plants and bacteria to less harmful substances. Using an example from Western France, Patty *et al.* [53] showed that grassed buffer strips reduced nitrate flow by between 47% and 100% at the agricultural plot scale. Roadside buffer strips filter run-off from streets containing various pollutants or eroded soil [52]. Vegetated buffer strips surrounding cultivated fields decrease soil erosion [51,54]. Buffer strips are one of the most cost efficient prevention measures for erosion control with the efficiency depending on the relationship between size of the cropland and of the buffer strip [55]. Many variables, such as slope grade and soil type, influence the effectiveness of the strips [56]. Using an example in South-West France, Morschel *et al.* [58] showed that large scale sediment deposition on roadways caused by intense spring and summer storms lead to significant cleanup costs. Modeling the effects of grass strips on soil erosion rates suggests that buffer strips of 12 m or 24 m width reduce sediments deposition best. Savings in the first year of planting are in the order of about 2% of estimated cleanup costs for 12 m wide strips, and of almost 35% in subsequent years for 24 m strips [58]. Margins have a range of associated fauna which some may be pest species, however, many are beneficial, either as crop pollinators or as pest predators [41,51].

3.1.2.3 Cultural services

Depending on their appearance, buffer strips can also contribute to the recreational appeal of landscapes by breaking up monocultures or increasing the aesthetics of water courses [52]. As traditional features in some landscapes, field margins may even have heritage values, give a sense of place, or are used for recreation, for example, by using them as jumps for horses during fox hunting or by enhancing game bird populations [41,47].

3.2 Maintenance of permanent grassland

The variety in types of grasslands across Europe is considerable, ranging from almost desertic types in South-East Spain, steppic and mesic types to humid grasslands, which dominate in Northern and North-Western Europe [58]. However, there is a commonly defined characteristic: Managed permanent grassland or permanent pasture (as opposed to natural, non-managed grasslands, a term usually used interchangeably) is according to the Commission Regulation (EC) No 1120/2009, art. 2(c) "land used to grow grasses or other herbaceous forage that has not been included in crop rotation of the holding for five years or longer." The value of permanent pasture for the environment has been recognized for a long time. This led to the introduction of a safeguard under the 2003 CAP reform to encourage the maintenance of existing permanent pasture and to avoid a massive conversion of pasture into arable land [20]. The rationale for including the measure 'maintenance of permanent grassland' as greening measure is that if the measure was tied to direct payments, it should be more effective in terms of conservation – i.e., agricultural area covered – than if the measure was voluntary.

3.2.1 Provisioning services

The wide extent of grassland in the UK [59] and elsewhere in Europe [58] is the result of its expansion by humans over centuries to provide grazing and fodder for animals 'supplying' meat, dairy products, and wool, as well as for keeping horses, which are used, for example, for agricultural labor or transport. Until today, grassland is a pivotal component of livestock production [60] and a potentially over-intensive use pose perils especially to small-scale farms [61]. Although hay might be used as biomass for energy production [59,62], there are considerable trade-offs, for example, with the increasing demands for agricultural products as well as energy crops and other associated forms of production [58].

3.2.2 Regulating services

Grasslands store approximately 34% of the global stock of carbon but unlike trees, where above-ground vegetation is the primary source of carbon storage, most of the grassland carbon stocks are in the soil [14,58]. However, whether grassland is rather a sink or a source depends on its management. Areas converted from arable land and maintained under well managed permanent grassland, as pastures or rangelands, constitute potential carbon sinks depending among other things on the degree of grazing [60,63]. Soussana *et al.* [64] described a range of management practices to reduce carbon losses and increase carbon sequestration: (i) avoiding soil tillage and the conversion of grasslands to arable use, (ii) moderately intensifying nutrient-poor permanent grasslands, (iii) converting grass leys to grass-legume mixtures or to permanent grasslands, (iv) increasing the duration of grass leys, and (v) using light grazing instead of heavy grazing.

In terms of regulation of water flows, the management of grasslands makes an important difference, too. Intensive grazing and the resulting soil compaction cause decreased infiltration and increased runoff, which both increase the risk of flooding and reduce the recharging of aquifers [65]. The concrete impact of permanent pasture on water quantity and quality depends on the alternative land uses considered. Laurent and Ruelland [31] compared several agricultural land uses and found that nitrate loads show the highest risk of leaching with corn, and the lowest with permanent pasture and temporary pasture. This confirms findings by Rode *et al.* [66], who demonstrated that conversion of arable land into pasture is very efficient in reducing nitrate leaching. Yet, taking the example of South-West England, Jarvie *et al.* [67] showed that concentrations of polluting nutrients derived from agriculture, such as nitrogen and phosphorous, are higher in intensive livestock pastures than in low-intensity grassland. Similarly, Galloway *et al.* [68] illustrated that intensive grassland production heavily perturbs nutrient cycling and potentially creates a very leaky system, in which nutrients are lost both into water sources, for example through NO_3-leaching, and into the air, for example as NH_3-emissions [69]. The same authors described soil compaction caused by agricultural vehicles and livestock traffic, and, even more relevant, the exposed soil surface while cultivation and reseeding as major contributors to increased soil erosion in intensive grassland systems. In certain areas, for example Crete, natural grassland has higher erosion rates than agricultural land [70]. However, depending on the kind, grasslands can reduce the risk of soil erosion by slowing down run-off and dispersing infiltrating surface water compared to areas with more homogenous and contiguous cropland [71].

Since extensively used grasslands support more species than intensively farmed land, a greater abundance of the former may enhance pollination services [59,60]. Öckinger and Smith [72] and Jauker *et al.* [73] could show that the abundance and species-richness of bees, butterflies, and hoverflies in arable fields is related to the distance of the fields from extensively used grasslands. While extensively used grassland has positive effects on pollination, Potts *et al.* [74] and Hönigová *et al.* [75] found that pollination services are hardly supported by intensively used pastures.

3.2.3 Cultural services

In terms of recreation and aesthetic landscapes, intensively managed meadows are of insignificant value [69,75]. On the contrary, extensively used grasslands are often associated with rare or traditional livestock breeds, which in turn are valued as providing aesthetic, cultural, and historical benefits, as well as genetic resources for future breeding programs [59]. Further, permanent pastures are part of cultural landscapes and are remnants of centuries of farming practices all over Europe [e.g., 58,59]. In addition, especially extensively used grasslands are known to have positive effects on the chances of survival for archaeological features and the information they contain [59]. Extensively used grasslands also have a great value for recreation and tourism as people are attracted by the birds, diverse plant life and open-air landscapes [58].

3.3 Crop diversification

Agricultural intensification and associated monocultures are known for their negative impact on a range of ESS [e.g., 76]. In order to address some of the negative consequences, crop diversification is considered as one prominent measure for a more sustainable agriculture in the future. The European Commission [77] defines crop rotation as “planned and ordered succession of different crops on the same field (usually lasting 3-5 years)”. More concretely the greening practice comprises that “a farmer must cultivate at least 2 crops when his arable land exceeds 10 hectares and at least 3 crops when his arable land exceeds 30 hectares. The main crop may cover at most 75% of arable land, and the two main crops at most 95% of the arable area” [8]. No specific crops can be required or excluded due to the rules of the World Trade Organization, but voluntary growth of leguminous crops should be encouraged [77]. This fact that crops cannot be specified, makes the assessment of impacts of crop rotation and diversification difficult as different crops have different effects on ESS.

3.3.1 Provisioning services

Crop rotation has neither mainly positive nor negative direct effects on biomass production for energy and biofuels. Compared to other energy cropping systems, crop rotation systems are comparable concerning the dry matter yield, but perform weakest considering energy use efficiency (20 GJ energy output per GJ energy input compared with, for example, willow with 99 GJ/GJ) [78]. However, for example West and Post [79] found that optimizing agricultural management, including practices like crop rotation, can contribute positively to the accumulation of soil organic carbon and even to the sequestration of atmospheric CO_2.

3.3.2 Regulating services

In terms of water purification, services depend on the different application rates of fertilizers and pesticides, and on the capacity of different crops to regulate leaching. Diversification schemes with a high share of crops with a long vegetation period develop a large mass of roots. This decreases nitrogen leaching to the ground water during critical periods for mineral nitrogen losses [80]. According to Hajjar *et al.* [81], the diversity of crop rotation can help to decrease or prevent erosion and has positive effects on maintaining and restoring soil fertility, leading to increased yields relative to monocultures [51,81,82].

Lin [83] stated that increased plant diversity can create biotic barriers against new pests by promoting natural enemy abundance. This finding was confirmed by a meta-analysis on 552 experiments in 45 articles published over the last ten years, accomplished by Letourneau *et al.* [84]. The authors found that a reduced amount of herbivores and/ or an increased number of their natural enemies is the result of increased crop diversity including intercropping schemes, inclusion of flowering plants, and use of plants that repel herbivores or attract them away from the crop. Overall, herbivore suppression, enemy enhancement, and crop damage suppression effects were significantly stronger on diversified crops than on crops with none or fewer associated plant species [84]. Yet, they also found that pest-suppressive diversification schemes had a negative impact on production, in part due to reducing densities of the main crop by replacing it with intercrops or non-crop plants. Recent studies have suggested that farm-level diversification can especially contribute to natural pest control in cases where wider landscapes are structurally simple [85]. In complex landscapes, however, adding farm-level complexity does not necessarily enhance the benefits of pest control services [76]. Pollinators, especially wild pollinators, benefit from crop diversification, which increases the resource availability for them [86].

3.3.3 Cultural services

A clear benefit that is derived from crop diversification relative to monocultures is the aesthetic value of the landscape. Mattsson *et al.* [87], for example, found in investigations in Sweden that people prefer a varying landscape. Similar conclusions were reached on a regional level in Saxony (Germany) and Satakunta (Finland) where respondents of a survey pointed out their enjoyment of the beauty of structurally diverse cultural landscapes, which can be destroyed by large areas of monocultures [12].

4 Discussion

From an empirical methods point of view, the analysis showed that a number of ESS, which are supported by the greening measures are well described by the literature. However, for a few ESS, no presumed linkages could be identified. In particular, effects of the measures on wild foods and air purification but also on cultural services beyond landscape aesthetic and recreation remain research gaps.

4.1 Diverse effects on ecosystem services

Content wise, the literature review revealed that the greening measures adopted affect the selected range of ESS in diverse ways. Not surprisingly, there is no single measure that is likely to have positive impacts across all ESS. In particular, crop production is expected to decrease substantially when the measures are implemented. A similarly downward trend is likely to occur also for other ESS, perhaps with the exception of the rather ambiguous effects on the production of biomass for energy and biofuels. As far as data are available, it seems that all other service categories, i.e., regulating and cultural services will be increased – or at least experience no clear negative effect – once the measures are implemented. This is true for all measures except for the intensively used grassland, which shows only positive impact for livestock. Thus, from an ecological point of view, this measure seems to have the least ‘greening’ effect. In turn, the review showed that the buffer strips as well as the extensively managed grassland will positively affect most ESS. This is to a somewhat lesser extent also true for the crop diversification and set aside. However, with respect to the latter, the direction of the impact is unclear for quite a few services. Among others, this is because it depends very much on how exactly the land set aside is managed, i.e., if there is any soil cover – and if so, which crop mix, and so on.

4.2 ESS trade-offs and synergies

Indeed, in terms of trade-off and synergies, Baldock and Beaufoy [88] pointed out that much depends on objectives being pursued with a measure. For example, the measure to maintain permanent pasture can support different ESS, which are almost mutually exclusive. Depending on which definition of ‘permanent’ is used, the ESS supported change. A true permanent pasture (rarely, if ever, cultivated or re-seeded, never ploughed, and more likely to consist of semi-natural vegetation) provides great benefits to constrain soil carbon losses. In the same time, it is likely that it positively impacts water quality and soil functionality [20]. This kind of pasture, however, does allow only extensive livestock production. A more flexible definition of pasture, for example with frequent re-seeding of specific plants, would allow high stocking densities and even the production of raw materials. Nevertheless, high stocking densities can especially endanger benefits for water quality. Trade-offs can also be found for other measures. ESS supported by crop rotation and set aside depend by and large on management and the plants chosen for cultivation. While some plants are good for soil fertility, others can be used as raw materials. Depending on the choice of plant and its management, synergies with other ESS will increase or decrease. Buffer strips will not provide the same benefits for valued species when harvested frequently for the production of raw materials and biomass for energy production.

These different possibilities raise the challenge of deciding, whose preferences count most, which also becomes apparent at the example of recreation. Many recreational opportunities benefit people in close vicinity. Recreation might, however, be disturbing for biodiversity, which may be valued by people at a much larger spatial scale. So, which preference should be given priority, especially when taking into account that the people in close vicinity might also be the ones, who are responsible for implementing policy measures [89]? Unlike policy makers on higher levels, actors, who implement policy measures on a local level, often have also considerable knowledge of the bio-physical, economic, and social context, in which measures are implemented.

4.3 Impacts are in the eye of the beholder

To understand the results of the review, it is important to consider that most reviewed publications conclude on negative or positive effects on particular ESS using different 'baselines' or alternative land uses. For example, intensively managed grassland negatively impacts most ESS and is only second best compared to managing the grassland extensively. However, opting for an intensive grassland use on formerly arable land might result in relatively better ecological outcomes than continuing ploughing and growing corn. Further, the concrete 'value added' or ecological effect of a particular measure varies according to natural site-specific factors. For example, it does make a difference whether a buffer strip is established in an otherwise intensively farmed area or in an already biodiversity-rich mosaic landscape, or whether slope, soil type, and soil cover indicate that there might be a problem with the run-off of sediments resulting in negative water quality downstream, or not.

In a similar way, the actual effect of the respective measures on ESS depends not only on 'what was there before' (alternative land use) and on natural site-specific factors but also on the prevalent farming systems and farm characteristics (incl. objectives, and technical and other limitations on part of the farms). In this context, also depending on the specific agricultural farm, implementing the various measures involves different production and opportunity costs. Thus, farmers might select measures, which are 'less intrusive' or cost-intensive, yet, which might not be the 'best' from an ESS point of view. Further, farmers could have an interest to not comply with all details of the measure implemented, or even with the whole measure if monitoring is difficult and the chances are good to 'get away' with it. In the extreme, if production, opportunity, and transaction costs become too high, farmers might decide to skip the 30% direct payments. Thus, given the high heterogeneity of ecosystems, ecological problems, and farming systems in the different regions of the EU, one might argue that the rather broad brushed and unspecific design of the measures and the limited portfolio of greening measures will in many regions not produce the expected positive effects on ESS and turn out to be not cost-effective, for example, as many farmers would implement the measure anyway, i.e., also without tapping the 'national envelope' [90].

5 Conclusions

Including the ESS concept into the design and assessment of policies would allow a systematic review of the consequences of measures for services beyond conventional environmental assessments. It can also help to identify and include services, which are otherwise easily ignored, and to make trade-offs explicit, not only between measures or with and without measures, but also how measures are precisely defined, i.e., which activities might be acceptable and which not.

Yet, even the most detailed literature review will not yield enough information to cover synergies and trade-offs of measures when taking into account the fact that they also highly dependent on site-specific factors such as soil, climate, slope but also management history that might change over time due to natural causes or to agricultural and other policies, which makes the challenge even bigger. The fact that synergies and trade-offs vary and much information is needed, poses a well-known problem for policy makers, namely the problem of making decisions on the basis of incomplete information or more simply making decisions under uncertainty. This problem is amplified by the fact that even if all services could be quantified and all synergies and trade-offs assessed, the preference of one service over the other would still cause the challenge of whose preferences count. As people from the local level are those, who are actually implementing policy measures and often have considerable knowledge, it is necessary to design policies, which include their views into decision making. While the subsidiarity principle already provides for some leeway in decision-making on agri-environmental schemes for the Member States, the process of properly designing these schemes is a rather complex negotiation process. On the one hand, there is only passive support for decentralized and participatory approaches to include local knowledge or needs. On the other hand, there are compulsory complex bureaucratic procedures on part of the EU. Thus, there are no incentives for the national or regional administrations in the Member States to actively support approaches for locally adapted schemes [91]. Further, such regional or local adaptation might also come at a price – higher costs for decision-making and, perhaps, monitoring compliance [6]. Yet, while frame or minimal conditions and/or 'no go's' should be defined at EU level – regional administrations might be given some more room for maneuver, e.g., by reduced bureaucratic burdens and possible some resources, to define regional 'interpretations' or 'fine-tuned' measures or details of allowed or not allowed activities within a particular 'measure'.

However, even when local knowledge is included, this is no guaranty that measures achieve what they were designed for. Successful implementation depends on an unknown number of complexly coupled factors, such as impacts of climate change, global markets, social and cultural perceptions, etc. In order to be able to react and adapt to new circumstances, consequences of policies must be continuously monitored and flexible in design. Therefore, it is necessary to quantify goals and determine baseline levels describing what the situation was before the measure against which progress is verifiable. Is this also a pledge for initiating systematic assessments of ESS for determining the measure and region-specific trade-offs properly? This would be a worthwhile suggestion, yet, it comes along with costs and knowledge needs and also might be tricky to make it compulsory. While for qualitative, yet regional-specific assessments, local stakeholders' expertise might be a suitable alternative, a systematic assessment requires more research on methods for estimating ESS delivery in different context conditions and land management types.

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