agronomy

MDPI

Review

Effects of Agri-Environment Schemes in Terms of the Results for Soil, Water and Soil Organic Matter in Central and Eastern Europe

Jana Poláková [1,*], Josef Holec [1], Jaroslava Janků [1], Mansoor Maitah [2] and Josef Soukup [1]

[1] Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences, 16500 Prague, Czech Republic; holec@af.czu.cz (J.H.); janku@af.czu.cz (J.J.); soukup@af.czu.cz (J.S.)
[2] Faculty of Economics and Management, Czech University of Life Sciences, 16000 Prague, Czech Republic; maitah@pef.czu.cz
* Correspondence: jpolakova@af.czu.cz; Tel.: +420-224-382-770

Abstract: Building on the agri-environment framework in Central and Eastern Europe, the article emphasizes the role and the use of the agri-environment in provision of different ecosystem services. It shows that relevant conservation measures with regard to ameliorating soil degradation contribute to the existence of sustainable land systems. In our study, we (i) identified what the soil water aggregate means, (ii) reviewed how agri-environment schemes (AES) function to support soil water requirements, and (iii) how appropriate soils are identified with regard to the implementation of soil conservation under the agri-environment. Empirical data were surveyed to assess AES as the pivotal subsidy in four countries: the Czech Republic, Hungary, Poland, and Slovakia. Quantitative data were assessed to contribute to evidence on and the expenditure effect of the measures. This review found that AES schemes in arable land systems implement several approaches such as cover crops and the reversion of arable land systems to grassland. The costs of AE measures reflect the costs of the particular agri-environmental practice and its constraints on commercial performance by the farmer. The AES budget analysis showed that subsidization moderately increased over the 2000–2020 time frame. However, the magnitude of the AES budget is still largely overshadowed by generic subsidies at farm level.

Keywords: soil; water; arable farming; grasslands; ecosystem services; carbon storage

check for updates

Citation: Poláková, J.; Holec, J.; Janků, J.; Maitah, M.; Soukup, J. Effects of Agri-Environment Schemes in Terms of the Results for Soil, Water and Soil Organic Matter in Central and Eastern Europe. *Agronomy* **2022**, *12*, 1585. https://doi.org/10.3390/agronomy12071585

Academic Editor: Francisco Manzano Agugliaro

Received: 18 May 2022
Accepted: 27 June 2022
Published: 30 June 2022

1. Introduction

Europe is a densely populated region that employs agri-environmental measures to conserve soil water. The political science surrounding the European agri-environment, in the vein of Cooper and Prager, has so far generalized the issue of soil conservation to understand and negotiate stakeholders' route into policy. Soil scientists examine the framework of ecosystem services [1] while social scientists neglect the soil water issue [2]. In our study we focused on soil water parameters constituting a key topic explored for the sake of improving knowledge on ecosystem services shared by ecologists, land managers and conservationists.

The role of the agri-environment was amply emphasized in the implementation of conservation measures to ameliorate soil degradation [3,4]. Thereby, agri-environment conservation intervenes in farm practice.

Soil water is the key factor in a plethora of soil science problems. Soil is not extrinsic to water. Soil water is therefore the basic aggregate for a functioning land system. For example, soil water determines terrestrial carbon stocks [5], notwithstanding the carbon stock of Central and Eastern Europe [1], thereby affecting changes in the role of organic matter within carbon storage. In this way, soil water affects ecosystem services wherewith crops co-exist with soil carbon [6]; in doing so, soil water affects how crops influence soil carbon storage in topographically diverse terrains. Through such ecosystem services, the soil water capacity interacts with soil organic matter [7], thereby enhancing the resilience of agriculture [8], namely in the periods of iterative droughts. Therefore, at the EU level, soil carbon storage is increasingly emphasized as the basic ecosystem service associated with land systems [9]. However, for measurements of soil carbon storage to be meaningful, sufficient experimental times must be set as needed to determine both terrestrial carbon stocks and water retention measurements [6]. In the research on which we report, the effects and effectiveness of agri-environment policies are assessed at the level of land systems, rather than at field or plot levels. This means that conceptual policy discussion is a process whereby one should be precise about the kind of policy to be developed. Therefore, this study identifies the agri-environment policy targets relevant to the ecosystem services encompassing soil water and soil organic matter and carbon storage. Sustainable outputs were for a long time negotiated to become targets, and the acceptance of soil water targets on the regional, vis-a-vis the EU, scale is important in the context of achieving climate-proof farm management. Pinpointing such regional problems with respect to soil water is critical for ecosystem services from land systems, hence a preliminary step in conceptual policy discussion [10].

The objective of this study is to re-assess the agri-environment policy as the key framework. The emphasis is on the array of agri-environment measures dealing with the ecosystem services. That is, the interaction between the requirements regarding soil carbon storage and soil water. We will (i) identify what the term 'soil water aggregate' means, (ii) how agri-environment schemes function to support soil water requirements, and (iii) how appropriate soils are identified regarding the implementation of soil conservation under agri-environment.

The task outlined is rather broad, as it has evolved in a way which is not amenable to experiment. Therefore, the empirical data survey was designed so that we would analyze four programs of European countries, focusing on Central and Eastern Europe. We analyze empirical agri-environment schemes that were implemented regarding ecosystem services pertinent to soil water. Finally, we evaluate how monitoring and verification should be parameterized to use the agri-environment experience to bring together evidence regarding ecosystem services relating to soil water and soil carbon storage (i.e., with respect to potential soil carbon schemes in regions where soil carbon schemes are yet to kick off).

2. Methods and Data

This study is a survey encompassing comprehensive literature reviews next to empirical data. The survey methods were designed in this way to be able to deliver relevant conclusions for the scientific community. The literature reviews were designed to apply the science database search. The evidence encompassed academic articles, reports, and public-level data archives. The keywords applied in the search were, alongside agri-environment schemes, soil water, soil organic matter, soil carbon, ecosystem services, cost, benefits, and effectiveness. In identifying the documents for reviews, we proceeded to include relevant evidence in the right moment. We surveyed 78 articles and source items, of these 31 were written by authors from Central and Eastern Europe or were the sources that covered this study area in more specific detail. Most sources deal with the topic more generally and do not focus on any specific part of Europe. Still, our reviews were designed to be relevant to the science and policy outputs we can interpret in foreign languages, hence largely the European bioclimatic, pedological, and environmental conditions.

The empirical data that is included in the survey is primarily based on analysis of agri-environment schemes (AES) included in the Rural Development Programme (RDP) documents that address the study area, i.e., the four countries that are accounted for. Apart from the Czech Rural Development Programme that was analyzed in the native language and the Hungarian Rural Development Programme that was analyzed in the precise English version, the rest of the countries (Slovakia and Poland) was analyzed in the respective foreign languages. The second leading source of the data was the Local Data Bank of the Central Statistical Office of the selected member states (CSO: Prague, Czech Republic; Warsaw, Poland; Budapest, Hungary; and Bratislava, Slovakia) and the Agency for Restructuring and Modernization of Agriculture (ARMA: Prague, Czech Republic; Warsaw, Poland; Budapest, Hungary; and Bratislava, Slovakia). The quantitative data regarding agricultural area per farm were sourced from the Eurostat country files, whilst the financial data were based on our own library construed from the fifteen-year-long documentation of the annual rural development budget by the European Commission. The simplified cost-effectiveness was modelled for two concrete agri-environment schemes. These were chosen because they were most frequently cited in literature regarding effects for soil water and soil organic matter. For illustration's sake, the cost-effectiveness of these agri-environment schemes has been accounted in two countries only (Czech Republic and Poland); for these schemes, the data referring to subsidization level (cost and subsidy per hectare) was gleaned from the annual reports by the official authorities of the Ministry of Agriculture and the Ministry of Agriculture and Rural Development.

3. Literature Reviews

3.1. Soil Water Aggregate

Unsustainable outputs by agriculture affect soils [11]. Therefore, soil water parameters were studied in our investigation not only because of the correlation with ecosystem services including soil carbon storage and cycling, but also because the overall soil characteristics influence sustainable production from agricultural land systems.

Abundant research has been devoted to ecosystem services from holistic land systems. Research also abounds with respect to broad brush estimates of the way in which soil water interacts with terrestrial soil carbon storage in land systems. By summarizing the very different estimates of soil carbon storage regarding the different farm, soil, and climate conditions of Europe's agriculture, Nowicki states that the carbon storage capacity of grasslands supersedes the carbon storage capacity of arable soils [12]. Still, it is just as important (i) to minimize adverse changes of land cover to retain precious grasslands with carbon stocks as it is (ii) to tune up soil practice on arable soils so as to avoid carbon oxide (CO_2) emissions from soils. Adequate land management and farm practices are pertinent to soil health in land systems [13]. Table 1 presents an overview of the changes in land cover with adverse effects on soil carbon storage in the EU. Still, the monitoring of ecosystem services, e.g., the monitoring and verification of soil carbon storage and changes in it, such monitoring relating to the question of how land systems change in adverse ways and how the soil practice in agriculture is responsible for such changes as such, is in an incipient phase. Notwithstanding the challenges facing monitoring and verification methods, several studies have dealt with the topic and will be discussed in Section 5. Research also abounds with respect to the pertinence of measures to compensate ecosystem services, for example, publicly funded agri-environment measures to be carried out by farmers in efforts to avoid adverse changes in land systems, i.e., measures for retaining soil water through appropriate conservation (Borrelli et al., 2016; de Nocker et al., 2013; EEA 2012 and 2013 [14–17]). In addition, there have been many investigations regarding the interaction of soil water with carbon flux between soils and the atmosphere [14–23].

Table 1. Adverse Land cover changes in EU agriculture from 1990–2000.

Conversion	Area (ha)
Pasture to arable land	657,916
Forest to arable land	17,540
Forest to permanent crop	5936
Wetland to arable land	3225
Pasture to permanent crop	2378
Wetland to permanent crop	34

Source: Nowicki et al., 2009 [10].

When water shortages occur, changes in soil water capacities result in increases in soil degradation because of oxidation and mineralization rates, with effects on soil carbon cycling and therefore on soil fertility and on how soil organic matter stores nutrients. Additionally, soil water is responsible for soil structure and the natural carbon fluxes between soils and the atmosphere [24]. The decrease in soil water is observable in reporting on adverse changes to land use systems (Table 1), both from systems with deep ecosystem services, e.g., a better holding capacity (grassland) and from shallow ecosystem services, i.e., worse water holding capacity (arable soils). The priorities for addressing soil water capacities vary considerably from place to place, even between different fields on the same farm. Central and Eastern Europe is increasingly exposed to adverse meteorological conditions [25,26]. Soil water capacity is a determining factor regarding establishing adequate soil tillage technology for reducing surface water runoff [27]. Soil water is conserved by a plethora of farm level measures, e.g., the return of arable land systems to grasslands [28–32]. Finally, the soil water concept is a determining factor in the complex calculations of soil carbon contents [33], it is relevant to state guidance on targets regarding small water retention up to specific deadlines [34]; and is a pre-requisite for ameliorating water deficits [35].

Soil water capacities and priorities can therefore be identified and articulated on a range of different scales [12]. Thus, soil water capacities are an essential property of soils. In science they are considered as useful parameters, although they are overshadowed by the focus on soil carbon storage in land systems. The estimation of soil organic carbon content in agricultural soil is based on measurements derived from plot samples, whilst soil organic matter and soil organic carbon are assessed in further detail by means of a conversion factor (Table 2).

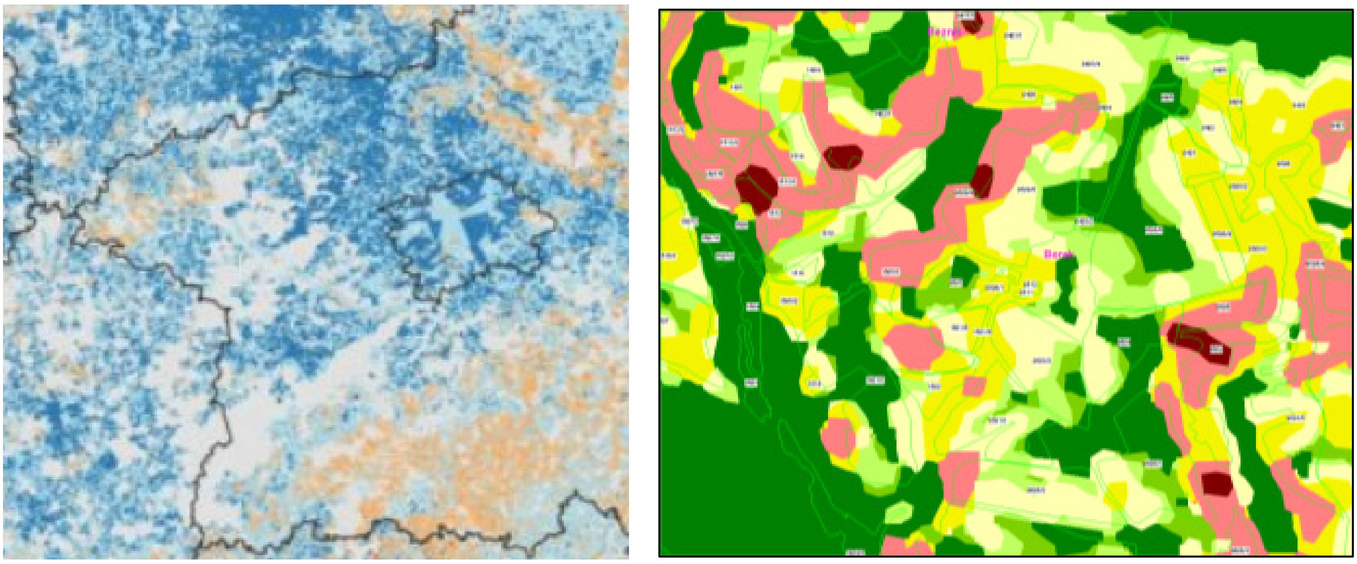
Table 2. Soil organic matter levels in arable soils.

Member State	Soil Organic Matter Levels	
	Mean Value (g/kg)	Total Contents in Arable Soils (Mtonnes)
Austria	28.9	262.1
Czech Republic	19.6	220.2
Germany	29.4	1335.8
Hungary	20.3	288.1
Poland	22.6	961.1
Slovakia	22.1	109.2

Source: Context Indicator CCI41, 2016. Note: four of the countries of Central and Eastern Europe are further studied in our investigation, Germany and Austria are annotated for the sake of comparison.

3.2. Identifying the Soils Relevant to the Agri-Environment

Whilst setting up any policy to conserve soils at farm level through implementation of the agri-environment, the prioritizing of soils is needed. Setting soil area priorities enables one to understand which soils require conservation and which levels of conservation via agri-environment implementation are adequate for the respective land use systems. One aspect is to preserve carbon-rich soils, with a focus on conserving healthy soils. Just as important is the focus to avoid further depletion of arable soils already low in soil carbon and soil water capacities. In sum, there is a dual focus on identifying soil areas. This has been matched with three broad approaches adopted by member states [36]. These include the following: wall-to-wall mapping based on legacy data at local and regional levels; the identification of land with certain characteristics (e.g., topographical factors regarding land use adequate for hilly terrains); and farm level soil assessments. Primarily, good tools for identifying priority soils at the regional level are maps and soil inventories structured on legacy data, as documented in Figure 1a (for the potential loss of soil organic matter levels) and Figure 1b (for potential risks to soil organic matter levels from erosion by water). Research documents the complexity of the structure of indicators regarding soil organic matter levels [37], via wall-to-wall mapping at local and regional levels.



(**a**) (**b**)

Figure 1. (**a**) Example of the Czech Republic's approach to the field-scale mapping of the potential loss of soil organic matter levels. Gradient: dark grey—no potential risk; yellow—moderate potential risk; red—greatest potential risk. (**b**) Example of the Czech Republic 's approach to the field-scale mapping of risk regarding soil organic matter levels because of erosion effects. Gradient: green, yellow—no potential erodibility; pink—moderate erodibility; red—severe erodibility. Source: Portál farmáře—Nový iLPIS, Sitewell s.r.o., 2010.

The other approach to identifying appropriate soils is the approach used in England and Germany, i.e., via farm-level assessment. The exercise proposed the following steps: farmers identify and annotate the problems (current and potential) with their soil; they assess and annotate soil degradation risks on their land; they select and implement appropriate measures from the government-regulated menu of conservation measures to prevent and/or remediate any problems; they review soils and measures each year as appropriate. Such a demanding approach was not implemented by Central–East European countries who identify soil areas for conservation by referring mainly to maps in the iLPIS tool and to topographical criteria common to the all the country, considering the diversity of topographical conditions.

3.3. Agri-Environment

3.3.1. Agri-Environment Schemes for Conserving Soil Water

The agri-environment encompasses schemes (AESs) that are traditionally understood at farm level as components of such voluntary practices that reduce or eliminate adverse effects of land use. Although the classic benefit is biodiversity, the secondary effect is to maintain existing soil carbon stocks [4], while also reducing soil carbon emissions. The practice amounts to conservation which is feasible for the farmer and able to meet basic requirements [38], this helps to achieve proportionate outcomes for ecosystem services, e.g., soil water requirements.

Table 1 documents how widespread the practices are that adversely affect soil water properties in agricultural management. At the same time, the table outlines the possibility of returning arable land to forest and grassland. Indeed, the return of arable land systems to grassland is a basic and largely applicable agri-environment scheme to enhance soil water capacity with the effect of enlarging the carbon storage capacity of soils. The return of arable land systems to grassland appears amongst significant measures regarded as determining factors in the adoption of adequate management practices [39]. Over the years, many have doubted the effectiveness of agri-environment measures (AES) for maintaining or improving biodiversity [40,41]. Yet, in the long-term, soil scientists emphasize the effectiveness of agri-environment practice for soil conservation [42], e.g., a return from arable land systems to grassland. In doing so, research has shown in detail for each country where it is applicable how soil conservation underpins the ecosystem services of soil carbon storage within agricultural land systems.

Agri-environment schemes (AES) are generally designed in the same way in each country, i.e., the actions are prescribed rather than voluntary. The actions are compared with the statutory agri-environment standard and farmers may enroll in voluntary agri-environment schemes based on incentives to conserve soil water and thereby obtain an agri-environment premium. Conservationists have raised doubts about whether financial incentives are appropriate levers in the case of farmers [3]. The novel carbon schemes, in contrast, fully rely on financial stimuli, as discussed in Section 3.3.2. Still the classic agri-environment relies on the fact that advising and training has a role at local and regional levels. This means that with regard to soil water conservation in each country, advising and training has to start from common methodological principles as well as differences in national surveys; thus, there are limitations in carrying out direct inter-country comparisons on absolute levels of soil water. The differences between how soil carbon is conserved, how carbon oxide emissions are avoided in arable land and grassland management, and how soil water conservation practice changes under different land uses as well as information on how these practices have changed between surveys, however, can be used to estimate changes in soil water with respect to basic standards, on the one hand, and future land use change at the country level.

Because AES measures must surpass, within the same kinds of conditions, basic standards relating to soil vegetation cover, the retention of terraces, standards for crop rotation and carbon content, permanent grassland, buffer strips, and the retention of landscape features, AES measures must be additional and proportionate to standards.

The bespoken structural feature, regarding the fact of the agri-environment being more demanding than basic standards, is woven into the rigorous protocols of the ecosystem services provided for soils by the agri-environment [3,4,38,43]. In this complex way, the agri-environment has linkage to a smaller territory than the basic standards associated with soil carbon [41].

3.3.2. Effects of the Agri-Environment in Developing Carbon Schemes

It is the national and regional administrator who technically devises the array of agri-environment measures to combat soil and water pressures on water resources. By comparison, carbon farming schemes represent either a market-based business strategy, or a community-driven mechanism, e.g., the community-driven mechanism for conserving soil carbon cycling in European soils [42] and a successful community project for conserving the environmental benefits of Irish turloughs, see [44]. Carbon farming schemes will be potentially implemented based on scheme protocols, developed by the carbon conservation community in practice (at local and national levels). In contrast to the publicly financed agri-environment, carbon farming schemes are not yet widely operational in Central and Eastern Europe. Compared with Northern and Western Europe, where carbon farming schemes represent a booming trend [9], Central and Eastern Europe is still building up the blueprint. These incipient carbon schemes will feasibly deploy the agri-environment experience to construct a community carbon fund depending on the scheme sponsors of leverage funds. The result of implementing the carbon scheme at farm level, in contrast to the agri-environment—whereby implementation at farm-level result is based on subsidy—is that the carbon conservation scheme supports soil water and soil biogeochemical and hydrological cycles, this for the economic and educational benefit of the farmer. The effect is measured at once by conservationists and stakeholders. Farm auditors are allowed to evaluate the stringency of protocols, to differentiate successful from unsuccessful schemes. The auditors will inspect the measured outcome of soil water conservation at farm level to award a certain number of carbon credits, and within the scheme remit, farmers will be able to use the credits obtained for soil conservation as an ecosystem service.

The credits are used in order both to promote enhanced soil carbon sequestration and to avoid the adverse effects of agriculture and deleterious consequences for soil water associated with conventional commercial practice. Scheme implementation thus involves stringent protocols, rigorous accounting for the specific soil ecosystem service via farm-level carbon credits in a carbon scheme, in contrast to the simple counting of hectares in the agri-environment. The similarity between agri-environment and carbon farming schemes is the establishment of monitoring and verification procedures regarding outcomes. The arguable prerequisite of a carbon scheme, in contrast to the statutory agri-environment, is the implementation of stringent protocols for the monitoring and verification of soils [45]. Notable is that the science for measuring soil carbon storage exists, yet the monitoring and verification procedures for such schemes have not yet been fully realized. Monitoring and verification, including the measurement of soil carbon contents, which will follow international measurements is proving problematic for soil science. It is only with the use of monitoring and verification procedures applicable to assessing farm performance, within agri-environment schemes (AES) focused on farm-level soil conservation as well as soil organic carbon sequestration, that efforts to implement any new carbon farming scheme on a contractual basis are feasible.

3.3.3. Agri-Environment Dependency on Basic Standards

How to quantify the relationship between measures and standards is not a straightforward discussion. This discussion focuses on statistical documents, official documents and articles closely related to the investigated issue. Our study is strategically positioned to focus on Central European rural areas, notably in the Czech Republic (in comparison to Poland, Hungary, and Slovakia). It aims at continually analyzing AES principles, their implementation, and minimum outcomes for soil water, carbon storage, and associated ecosystem services from the point of view of the agri-environment indicators.

The basic standards refer to maintaining land in a good agricultural and environmental condition [14]. Three topics with six genera of basic standards focus on soil water protection [14], for example, with respect to soil vegetation cover, the retention of terraces, standards for crop rotation and carbon content, permanent grassland, buffer strips, and the retention of landscape features. The dynamic of negotiating the standard reference line therefore also affects the way soil water targets are built upon within the measures that are more advanced (and voluntary for farmers; OECD 2012), i.e., the agri-environment schemes (AES) focusing on soil water targets including soil carbon storage and water retention. The farm-level adoption of soil conservation measures may thus be either a result of the autonomous decision of the farmer [46], a result of enforcement of basic standards, a result of advice and financial stimuli by the agri-environment schemes (as per Regulation EU 1782/2003), or, in the future, the advice and business strategies of carbon farming schemes.

The effect in the Czech Republic is that the agri-environment relates to only 14.2% of the agricultural area, as far as soil protection is concerned, and 21.5%, where water protection is concerned. This is within the range of the one-tenth to almost one-quarter of the total agricultural area at the EU level that is devoted to more demanding conservation regarding soil water and soil carbon storage, such that is implemented via agri-environment policy. The practice mainly involves reversion of arable soils to grasslands; the implementation covers crops, winter crops, and spring crops; under sowing; organic farming; and extensification (such as technologies to reduce water erosion). The agri-environment measure was introduced as a component of state aid for farmers; the initial budget was especially aimed to support extensively farmed landscapes in 1997 (in the Czech Republic). Consequently, the agri-environment measures are implemented to date under EU funds. Still, it is an essential long-term project to induce land managers into following a more demanding environmentally friendly practice when such practice must go beyond basic standards, e.g., with respect to soil vegetation cover, the retention of terraces, standards for crop rotation and carbon content, permanent grassland, buffer strips, and the retention of landscape features. One of the stable agri-environment schemes, the illustrative example of returning arable land systems to grasslands, is based on, and goes beyond the standard for soil carbon and crop rotations.

3.4. Soil Water Targets

European agricultural policies are guided by multiple objectives within the policy cycle, of which a pivotal objective is the provision of public environmental goods [47]. Cooper and Prager go to great length to explain how to finetune ecosystem services, the bespoken goods, within AES conservation at farm level. The points are that AES implementation is relevant to farm management, payment schemes are incentives, and the farmers receive sufficient advice on AES aspiration as well as implementation. This flexibility should not morally compromise the targets, which are set to maintain natural resource pathways in the EU. In particular, regarding a water quality policy pathway, the policy target is to achieve a good status regarding nitrate use in surface and underground water (European Commission 2010). The role of nitrate filtration by soils is key. A complementary policy undertaking is to promote the sustainable use of water and to mitigate the effect of droughts (Communication on Water Scarcity and Droughts). There is no formal EU target for the policy regarding the retention of soil water (European Commission 2021 [9]). The reason is that the proposed Soil Framework Directive, in negotiation from 2007 to 2011, was not approved by EU Member State leaders (although the directive was accepted by the European Parliament and was supported by Eastern and Central European countries, according to the seminal work by Trnka et al., 2009 and 2011 [48,49]. Therefore, only the Soil Thematic Strategy is relevant to research data collection and the preparation of actions, including soil carbon maps and tools and soil water research actions. The complete directive itself did not make its way through the negotiating agenda at the EU level [36,50] until the recent adoption of the 2030 Soil Strategy. The lack of binding targets based on a unified soil directive has become all the more salient given that the meteorological conditions with effects on soil moisture (e.g., temperature as shown in Figure 2) in Central and Eastern Europe have evolved to the detriment of soil status.

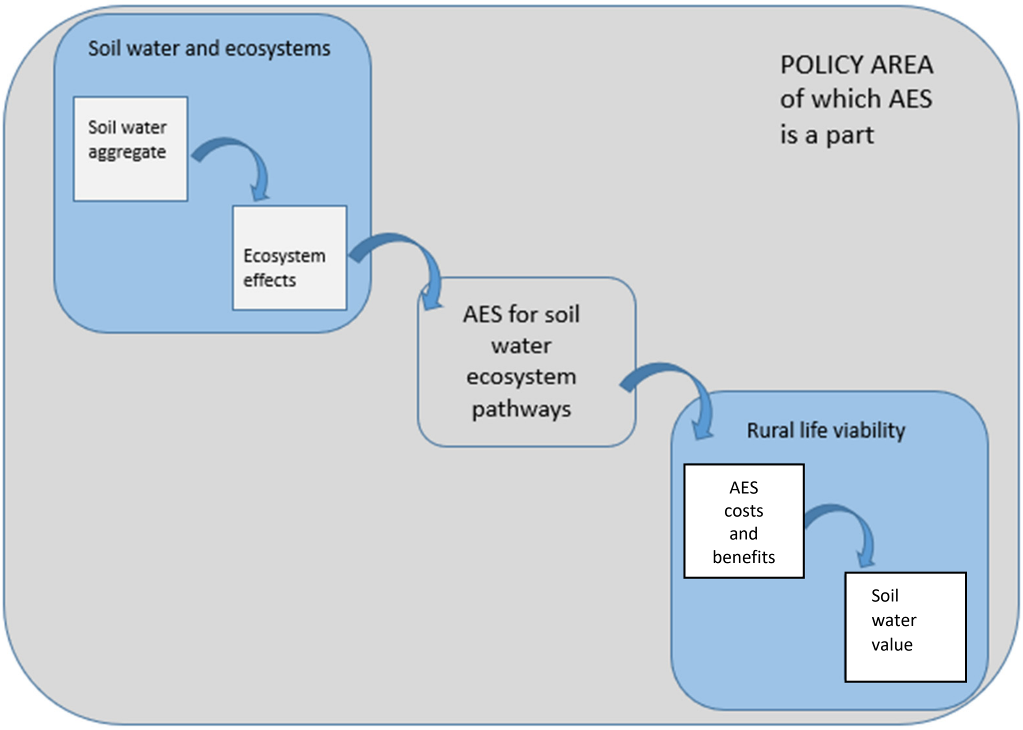


Figure 2. Policy area of which AES is a part.

Opponents of the soil directive were against EU intervention into the area of farm-level soil conservation per se. Such intervention was viewed as political interference to influence the outcomes of national government elections. The opponents judged that only farmers have the right to assess what are sufficient or insufficient soil carbon levels. The veto came despite the obvious fact that the EU Soil Framework directive was a modern tool, delegating most decisions about soil-related targets to the presumed actors of the Member State. Soil water protection targets, derived from soil water research at EU level, must hence be negotiated according to the Soil Thematic Strategy at local, regional, and supra-regional levels.

The targets affect how ambitious the local and regional actors are in establishing basic (and compulsory) standards (Section 3.3.3) and, further, how aspirational the agri-environment schemes (AES) focusing on soil water retention and soil carbon cycling are (Section 4). Starting from the agri-environment policy work by [40,51] (Cooper 2006 and 2009) and [43] (Prager 2008), Trnka et al. [48] also alerted to the importance of achieving several elements of soil water targets (a water quality pathway, the effect on drought management, nitrate use and the soil water conservation pathway). These targets had to be considered in AES for such schemes to be credible regarding the provision of environmental public goods by rural development programs after 2020.

4. Empirical Data Survey with Regard to Soil Water Measures Implemented under the Agri-Environment

4.1. AES Formula

Taking up the above topic, we were motivated by the need to summarize how AES measures are technically composed at national or regional levels to suit aspects of soil carbon storage relevant to the biophysical, bioclimatic, agronomic, and adaptive conditions at local–regional levels. These governance levels epitomize the policy area of which AES is a part (Figure 2). In addition, repercussions for biodiversity are dealt with in such a way [38]. Regarding the AES measures relevant to soil water retention, the formula must consider the practice done by the farmer. The empirical data of the four member states were sourced from and the Rural Development Programmes (RDPs) by the Czech Republic, Hungary, Poland, and Slovakia from 2014–2020. The second leading source of the data was the Local Data Bank of the Central Statistical Office of the selected member states (CSO: Prague, Czech Republic; Warsaw, Poland; Budapest, Hungary; and Bratislava, Slovakia) and the Agency for Restructuring and Modernization of Agriculture (ARMA: Prague, Czech Republic; Warsaw, Poland; Budapest, Hungary and Bratislava, Slovakia). The obtained data from the RDPs, ARMA, and CSO on soil conservation topic based on standards/number of associated agri-environment measures; soil vegetation cover, standards for crop rotation and carbon content, permanent grassland, establishing buffer strips, and retention of landscape features, as shown by Table 3.

Table 3. Agri-environment schemes focusing on soil water and soil carbon sequestration according to the basic soil standards.

	Soil Conservation Topic Based on Standards /Number of Associated Agri-Environment Measures				
	Soil Vegetation Cover	**Standards for Crop Rotation and Carbon Content**	**Permanent Grassland**	**Establishing Buffer Strips**	**Retention of Landscape Features**
Number	**12**	**13**	**24**	**6**	**3**
Czech Republic	*Sustainable land management:* Cover crop undersowing; reversion of arable to grassland; reversion of bare field waterways to grassland D/4	*Sustainable land management:* Cover crop undersowing; reversion of arable to grassland; reversion of bare field waterways to grassland. *Environmental practice:* integrated production; organic farming D/4; R/1	*Extensive grassland management:* Meadow conservation Pasture conservation R/9	*Sustainable land management:* Reversion of arable to grassland alongside the water course D/2	0
Poland	*Soil and Water protection:* cover crop undersoing; winter cover crop; spring cover crop. *Sustainable farming:* cover crop requirement in nitrate vulnerable zones D/4	*Soil and Water protection:* cover crop undersowing; winter cover crop; spring cover crop. *Sustainable farming:* limits on the use of nitrate fertilizer in nitrate vulnerable zones and alongside watercourses; organic farming D/3; R/1	Extensive farming, especially in Natura 2000 R/7	*Sustainable farming:* Buffer strips—2 m alongside water courses, 5 m alongside watercourse; 2 m in-field, 5 m edge-of-field W/4	Soil and water protection: maintenance of landscape feature requirement W/1
Hungary	*Arable schemes:* Erosion measures—water Erosion measures -wind Agrotechnical technologies D/3	*Arable schemes:* Soil conservation and crop rotation within integrated farming Soil conservation and crop rotation within organic farming D/2; R/2	*Grassland schemes:* Extensive grassland management Establishment of grassland on arable soils R/1	0	*Wetland schemes:* Reversion of arable soils into wetlands W/1
Slovakia	*Sustainable farming:* Reversion of arable to grasslands D/1	*Sustainable farming:* Integrated production Organic farming Protection from erosion—arable Protection from erosion—vineyards Protection from erosion—orchards D/4; R/1	Grassland schemes: Extensive farming, especially in Natura 2000—7 variants R/7	0	Landscape schemes: Maintenance of landscape feature requirement W/1

Note: Focus on soil topics identified for ecosystem services: R—protection of sequestered carbon; D—protection of soils at risk of carbon depletion; W—protection of soil areas identified as storing soil water capacity. Source: own analysis of the 2014–2020 Rural Development Programmes by the Czech Republic, Hungary, Poland and Slovakia.

The empirical data of four member states document the prevalence of the following: reversion of arable soils to grasslands; the implementation cover crops, winter crops and spring crops; under sowing; organic farming; and extensification (such as technologies to reduce water erosion), as shown by Table 3. Each one of these standards is broadly seen as a land-system management standard. Each one of these standards is a basic condition for implementing agri-environmental conservation. Because AES measures must surpass, within the same kinds of conditions, these basic standards, the linkage of AES measures to standards is not a straightforward discussion. A robust governance framework is indispensable for setting out the payment formula to balance the forgone income component and the costs accrued because of the farmer's implementation of the measure. The formula is the same from one country to the next [52]. This equality saves money and costs and avoids the risk of implementing vastly divergent measures in the absence of an EU framework. The finance comes from Pillar 2 of the common agricultural policy (CAP) aiming to support land-based measures for rural development. EU finance is founded in tandem with national co-financing.

4.2. AES Implementation with Regard to Soil Water Measures

Table 3 offers an overview of how AES is implemented in the Czech Republic, Poland, Hungary, and Slovakia. We surveyed empirical data on these four countries. For instance, the Czech Republic's agri-environment implements conservation measures linked to soil water retention targeting (a) arable land systems (whereby the deficits in soil conservation are salient) and (b) grasslands (whereby soil conservation supports carbon characteristics).

AES in arable land systems implements cover crops, and the reversion of arable land systems to grassland. Reduced tillage is part and parcel of organic farming schemes; experimental data from the field show that the soil water capacity of arable land systems is dependent on the kind of tillage (depth, subsoiling, and shallow) and that there is an approximate correlation between the soil water indicator, soil organic matter levels, and the "cation", i.e., soil carbon storage [53]. For most arable AES schemes, the result of enhancing the soil status of plausibly depleted arable soils is yet to be measured. The measurement needs to be based on climate-proof monitoring and verification systems, as well as directly on rigorous soil indicators (Janků et al., 2022; Zizala nd. [37,54]), such as the indicator of soil water retention and the indicator of carbon sequestration.

Moreover, AES in grasslands is focused no less profoundly on the soil water agenda. Grassland AES declare biodiversity as the primary objective. Still, soil conservation by means of extensive grassland schemes is traditionally achieved based on environmentally and economically beneficial outcomes for soil organic matter levels [55]. This means that the result would be supported if it was measured by climate-proof monitoring and verification systems, directly on the basis of rigorous soil indicators, such as soil water retention and carbon sequestration.

4.3. AES Costs and Benefits

The costs of AES measures reflect the costs of the particular agri-environment practice, and hence the value of the respective ecosystem service. With regard to soil water retention in arable systems the practice encompasses the reversion of arable soils to grasslands; implementing cover crops, winter crops and spring crops; undersowing; organic farming and extensification (such as technologies to reduce water erosion). Agri-environment schemes have so far implemented soil carbon maintenance via reduced and zero tillage only within organic farming schemes in the four countries. Further, as a form of payment for ecosystem services, the agri-environment encompasses subsidies referring to constraints on commercial performance by the farmer.

Costs of AES measures in general encompass three items: expenditure (e.g., reading the guidance, keeping records, and sometimes investment in inputs, such as seeds for the reversion of arable to grassland); revenue forgone (e.g., grassland is a form of unproductive set-aside); and costs saved. Overall costs amount to the AES budget of each individual country. Table 4 presents the AES budget for the four countries in Central and Eastern Europe analyzed in Section 4.1. Figure 3 shows the temporal unfolding of the AES budget at the EU level, in comparison with the total costs of the common agricultural policy in the 2000–2014 time frame. The figure clearly demonstrates the increase in the subsidization of European agriculture after the accession of Central and Eastern Europe, associated with the increase in the AES budget, hence AES moderately increases costs to the taxpayer. Furthermore, the visual shows how tiny the AE budget is in the data on subsidies for farmers. The effectiveness of these subsidies was not easy to verify, although the preliminary assessment of cost-effectiveness is detailed in Table 5. The simplified modelling of effectiveness was carried out for only two agri-environment schemes in two of the four countries. For the Czech Republic, the cost-effectiveness is documented in the example of AES buffers and AES reversion of arable to grassland. For Poland the effectiveness is detailed by using of the example of agri-environment buffers and cover crops. However, there should be no false claims on the preferability of scrapping the AE budget because of unproven effects on soil and water, given how large the overall subsidies with feasibly deleterious effects on soil water and soil carbon sequestration are.

Table 4. Member state allocation to agri-environment measures, 2007–2013 (Mio Euro).

	Overall Budget (Mio Euro)	Agricultural Area (ha)	Unit Budget (Euro ha^{-1})
CZ	841.0	3,491,470	240.97
HU	873.9	4,656,520	187.53
PL	1853.0	14,409,870	128.59
SK	248.0	1,901,610	130.52

Source: own compilation based on [47] European Commission 2015. Note: The unit budget has been calculated and indicates the relative weight of agri-environment subsidies in the country, overall, and per hectare of agricultural area. It does not show farm-level payments.

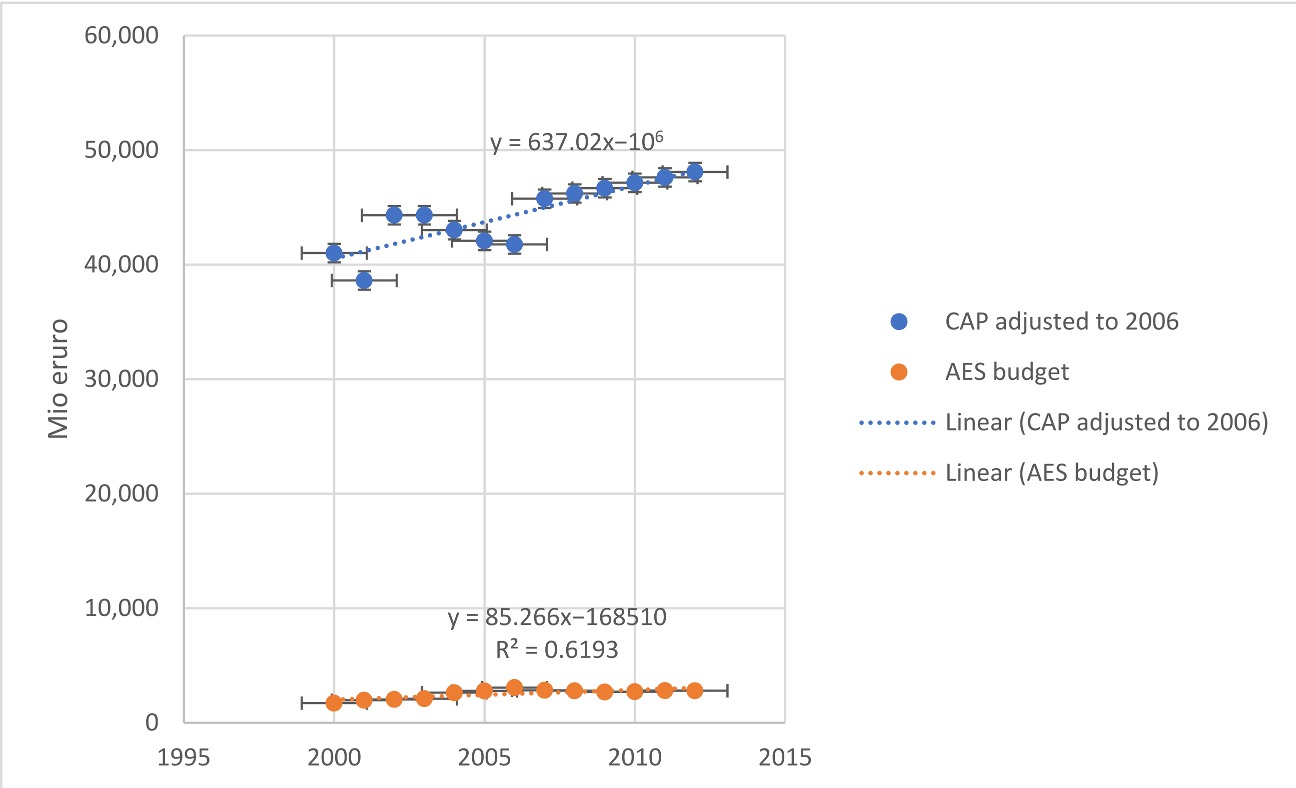


Figure 3. Temporal unfolding of the agri-environment budget in the 2000–2012 time frame in comparison with CAP subsidies.

Table 5. Cost effectiveness of AES in two member states.

	Cost EUR/Farm	Average Area per Farm	Baseline Cost EUR/ha	Farm Subsidy [(a)] Eur/ha	Baseline Share of Farm Subsidy (%)	AES Cost EUR/ha	AES Multiple of Farm Subsidy
CZ Buffers	2660–5320	133	20–40	198	10–20	337	1.7
CZ Reversion of arable to grassland	5600–8960	280	20–32	198	10–16	413	2.1
PL Buffers	220–440	11	20–40	179	8–15	337	1.9
PL Cover crops	320–464	8	40–58	179	8–15	104	0.6

Source: Agra facts 2019. Note (a): includes basic payment and ecological supplement.

To implement AES correctly, costs at the farm level matter because farmers' role in the provision of ecosystem services implies extra costs and/or income forgone. Thus, according to [38] (Cooper et al., 2009), farmers need to be incentivized to pursue certain farming practices in order to maintain landscape features and restore and maintain the management of natural resources such as water and soils. In other words, the AES budget reflects the fact that society has to purchase what amounts to a reallocation of resources to underpin the provision of public goods. The idea pushes us to revisit the sphere of carbon schemes.

4.4. Remaining Questions with Regard to AES Costs and Benefits

In Europe, the basic triad of costs (expenditure, revenue forgone, and costs saved) was occasionally enhanced with the term opportunity cost. For example, the opportunity to shift part of the CAP with the effect of displacing part of the arable schemes budget towards the agroecology budget was emphasized by recent research [56]. The authors claim that such farms that implement agroecology already did contribute to providing quality food, employment, and public goods [56]. Whereas van de Ploeg et al., emphasize all of these broader ecosystem services and goals, we focus on soil water and soil carbon storage from AES conservation. According to van de Ploeg's account, how will the cost be distributed? This is key in a very crucial way. Should the existing AES help farmers not only with soil and water outputs but also stimulate food production? Or could AES intervene at all if there is a "wholly unsatisfactory situation for EU taxpayers' money" [56]? Or should such effective AES reversion to grassland on all farms be paid for only on organic farms, according to de Ploeg, when implemented for the sake of certified food quality? Should the CAP budget pay more for this AES? Or should funding of the reversion to grassland on all farms be decreased? One could reason that its effectiveness (44%) is still lacking (vis-a-vis the ideal of 100%) and, thus, that all remaining soil conservation measures with more variable effects on different farms with all kinds of soils should receive greater funding. It remains unclear whether greater funding is a task to be assigned again to common agricultural policy, in van der Ploeg's concept, or if we have gone to the limit where the carbon funding schemes should bear the brunt of funding.

5. Discussion and Conclusions

Our study surveyed data on the meaning of soil water aggregate; the ways in which agri-environment schemes function to support soil water requirements, and how appropriate soils are identified with regard to the implementation of soil conservation under agri-environment. This means that covered in some detail soil conservation regarding soil water and soil carbon storage and cycling via the implementation of agri-environment schemes (AES). Empirical data were surveyed for the prioritization of soil related agri-environment schemes in 4 countries in Central and Eastern Europe. Although the array of soil conservation measures includes several options for arable land systems as well as grasslands, we focused on the schemes most emphasized by each of the countries studied with regard to soil water and soil organic carbon, i.e., the reversion of arable land systems to grassland and the buffer strips. The AES budget analysis showed that subsidization moderately increased over the 2000–2020 time frame, the increase probably resulting from the accession of Central and Eastern Europe countries. However, the magnitude of the AES budget is still largely overshadowed by generic subsidies at farm level. We assessed the AES cost-effectiveness, referring to two specific measures (reversion of arable to grassland and buffers). It was found that effectiveness can be expressed as the ratio of the baseline share of farm subsidy (%) as the minimum value and as the ratio of the AES multiple of farm subsidy as the maximum value. Our research echoes the finding on the effectiveness of agri-environment schemes [57]. The research assessed the AES results for soil water and soil organic matter at the level of agricultural sector in Europe. Although the overall evidence was variable, it suggests that agri-environment measures delivered soil water and soil organic matter benefits in improved grasslands and intensive croplands. There are a number of examples of agri-environment schemes that have been successful in maintaining soils of semi-natural grasslands, mountain grasslands and over-grazed pastures.

Whereas other researchers focused rural development on regional dissimilarities [58], and sustainable water management locally [59], we heeded the advice by Kastner et al. [60] with regard to the imperative of globalization. Therefore, we aimed to support the field by emphasizing soil conservation with regard to soil carbon sequestration under the agri-environmental (AES) policy funded from European rural development.

Our study concurs with the knowledge that adverse maintenance of agricultural land, with the effect of worsening soil erosion, also means a greater potential loss of soil organic matter (Vávra et al., 2019 [61]). Soil conservation hence affects ecosystem services [62] and soil water and soil carbon storage [63]. However, we argue that it is urgently necessary to develop accurate and climate-proof soil organic carbon indicators that need to be plausibly implemented into the monitoring and verification of agri-environment schemes. We need to know precisely to what degree AES conservation is successful. It is not enough to prepare result-based schemes to enable farmers to count rare flowering plants on their land as a counter value for their payment [64]. Implementing rigorous methods and climate-proof soil indicators is necessary for ecologists, conservationists, and administrators to be able to run AES focusing on the maintenance and enhancement of soil organic matter levels.

The topic of the effectiveness of agri-environment schemes with regard to implementing ecosystem services such as soil water and soil carbon conservation is a mainstay of the literature. We analyzed the finding that the reversion of arable land systems to grassland is 44% effective, one of the best outcomes with respect to the effectiveness of soil conservation measures at the farm level [65]. Despite this, research cannot effectively resolve the tension between financial stimuli for farmers involved in the implementation of ecosystem services, and the societal respect for farming based on yield, crop appearance, and livestock.

Historically, the cost of soil conservation is a subject that has been vigorously assessed at global level [66–69]. The authors performed invaluable analysis to understand the cost barrier to implementing soil conservation at farm level. Still, the current demand is more for elaborating local and regional indicators.

How to overcome the tension between collaborative approaches to implementing the agri-environment, which has been assessed many times by social science, remains a key issue for further research. Feasibly it is going to affect any carbon scheme implemented in European conditions (stressed by British ecologists and conservationists [3,4], alongside a Dutch conservationist constituency) and farmer-led approaches (Krupek et al., 2022 [70]). Collaborative approaches must inevitably involve the theory of planned behavior, the effects of which were doubted by skeptical sociologists (Wauters et al., 2010 [71]); therefore, we ask why would it turn out differently for carbon schemes than for the agri-environment? Is there any difference for the farmer facing the theory of planned behavior when the scheme is funded by the state (agri-environment) and when it is funded by private–public carbon funds? Whilst Europe at large has had the chance to study collaborative approaches for operational carbon farming schemes, the Central and Eastern Europe region is building up an incipient carbon scheme that may provide a preliminary answer.

The agri-environment policy has evolved over the thirty years of its implementation in EU rural development programs in a way that farmers are accustomed to soil conservation requirements, procedures, and stimuli. Rounsewell et al., 2004 [23] notes the importance of implementing cover crops and the reversion of arable land systems to grassland through AES policy; Moran reports the carbon effectiveness of such measures. Our research documents the prevalence of agri-environment schemes for soil conservation via the implementation of cover crops, winter crops and spring crops; undersowing; organic farming; and extensification within arable and grassland schemes. Others pinpointed the smart distribution of land as a helpful approach (Kadlec et al. [72]) to support carbon sequestration. Yet research lacks perfect blueprints to implement soil science expertise in local schemes under sponsored carbon funds. This qualifies the policy to be used for novel modes of implementing soil science. The purpose is to stimulate farmers to participate in new carbon schemes and carbon trade, certifications, and environmental footprinting (Dabkiene et al., 2021 [73]).

Employment in Central and Eastern Europe agriculture is reported by Debicki et al. [69] with a relevancy for soils. The World Bank reports on employment in agriculture in a comparable format. Poland and Hungary are countries with prevailing agriculture (25% and 4.61% of the workforce), Czech Republic and Slovakia report only 3.46% and 5.77%. From the figures, it is plausible to suggest that agri-environment schemes (AES), by implementing sustainable soil carbon practice, may be attractive for more qualified young farm employees. Therefore, we concur with the finding by the European Parliament (2016 [74]) that the CAP has a role in improving rural jobs.

One should be cautious, though, about indiscriminate community pressure on farmers, propagating soil sequestration practices in arable land systems. Research noted cases when compensatory and adverse land system conversion (see Table 1) has happened elsewhere [75,76]. This kind of adverse change should be avoided in the construction of carbon schemes.

In the current agendas, we heeded the shift from the earlier focus of AES studies (such as experimental measurements on the effect of regular applications of organic vs. synthetic fertilizers) to the current focus on the soil water and soil carbon cycling aspects relating to the current land sparing and land sharing approaches to optimizing agriculture [77,78]. Still, it was feasible to concur with researchers who explored soil conservation practices in an identical selection of Central and Eastern Europe countries [79]. The similarity lies in the fact that conservation optimized soil quality and soil organic matter, although we differ from Larramendy et al. [79] in that our survey did not directly examine experimental plots.

Whereas our study focuses on agri-environment schemes relevant to soil water and soil carbon cycling, elsewhere in Central and Eastern Europe, agri-environment has been understood largely as biodiversity protection [80,81]. The authors emphasize that a conceptually designed scheme may have more functions (e.g., schemes supporting the reversion of arable land-system to grasslands work for soils and work for water) but tailoring and targeting the primary focus is the key. With our local data gathered empirically, it was feasible to subscribe to [82] in stating that European agricultural policy, at large, should be more and more tailored to the careful management of soil carbon.

For instance, soil conservation through a more demanding agri-environment is, in Europe, typically paired with flat payments to disadvantaged territories. The evolving support in the policy cycle was starting in 2015 and demonstrated a positive trend. An increase in finance has been identified with regard to stabilizing the available rural development budget for the policy priority "Restoring, preserving and enhancing agroecosystems" [83]. There has been a marginal strengthening from just over one-half of the overall budget (as regards 2007–2013) to around 66% (regarding 2014 and beyond).

In conclusion, the goal of our investigation was to re-assess the soil ecosystem services provided by agri-environment policy as the key framework. An emphasis was on the suite of agri-environment measures focusing on the interaction between the requirements regarding soil carbon storage and soil water. The agri-environment implements farming practices which increase organic matter inputs to the soil and reduce soil disturbance. Existing schemes in Central and Eastern Europe emphasize the reversion of arable soils to grasslands; the implementation cover crops, winter crops and spring crops; undersowing; organic farming; and extensification (such as technologies to reduce water erosion). The schemes that were demonstrated with regard to cost-effectiveness are the reversion of arable soils to grassland and the buffers. The schemes have yet to include soil carbon maintenance via reduced and zero tillage. However, state-funded agri-environment schemes have so far only partially been able to prompt sustainable practice associated with ecosystem services for soils, alongside the primary commitment of agri-environment schemes aimed at biodiversity. Farmers of Central and Eastern Europe are accustomed to the tailored and targeted agri-environment schemes aiming to conserve soils, soil water and soil organic matter levels. Such schemes were established from the beginning of the implementation of the agri-environment in the region. The CAP rural development programs from 2023 (i.e., "CAP Strategic Plans") onward will mobilize on the basis of this policy experience. In doing so, the implementation of agri-environment schemes will feasibly contribute to ecosystem services summarized by the Soil Thematic Strategy. Still, the recent evolution with respect to prompting farmers towards participation in carbon farming schemes, implemented as business strategies in contrast to the agri-environment, is in its incipient phases. Carbon farming schemes depend on the implementation of soil science. Science should strengthen the elaboration of rigorous monitoring and verification protocols, in order to document the soil benefits of such schemes. Such a task is important and is yet to be the focus of efforts made by relevant stakeholders. The agri-environment offers a partial basis from which to start.

Author Contributions: Conceptualization, J.P. and J.S.; methodology, J.P. and J.S.; formal analysis, J.P. and J.J.; investigation, J.H. and J.J.; data curation, J.P.; writing—original draft preparation, J.P., J.J. and J.H.; writing—review and editing, J.S., M.M. and J.P. All authors have read and agreed to the published version of the manuscript.

Funding: This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862695 (EJP Soil) and co-financing from the Ministry of Education (MŠMT).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All the data are provided in this paper.

Acknowledgments: Many thanks to anonymous reviewer who helped us finetune the text of the paper.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Batjes, N. Carbon and nitrogen stocks in the soils of Central and Eastern Europe. *Soil Use Manag.* **2002**, *18*, 324–329. [CrossRef]
2. Dwyer, J.; Short, C.; Prazan, J. Fostering resilient agro-food futures through a social-ecological systems framework: Public–private partnerships for delivering ecosystem services in Europe. *Ecosyst. Serv.* **2020**, *45*, 101180. [CrossRef]
3. Prager, K.; Reed, M.; Scott, A. Encouraging collaboration for the provision of ecosystem services at a landscape scale—Rethought agri-environmental payments. *Land Use Policy* **2012**, *29*, 244–249. [CrossRef]
4. Prager, K.; Schuler, J.; Helming, K.; Zander, P.; Ratinger, T.; Hagedorn, K. Soil degradation, farming practices, institutions and policy responses: An analytical framework. *Land Degrad. Dev.* **2020**, *22*, 32–46. [CrossRef]
5. Blanco-Canqui, H.; Ruis, S.; Holman, J.; Creech, C.; Obour, A. Can cover crops improve soil ecosystem services in water-limited environments? A review. *Soil Sci. Soc. Am. J.* **2021**, *86*, 1–18. [CrossRef]
6. Beehler, J.; Fry, J.; Negassa, W.; Kravchenko, A. Impact of cover crop on soil carbon accrual in topographically diverse terrain. *J. Soil Water* **2017**, *72*, 272–279. [CrossRef]
7. Hänsel, S.; Ustrnul, Z.; Łupikasza, E.; Skalak, P. Assessing seasonal drought variations and trends over Central Europe. *Adv. Water Resour.* **2019**, *127*, 53–75. [CrossRef]
8. Trnka, M.; Balek, J.; Štěpánek, P.; Zahradníček, P.; Možný, M.; Eitzinger, J.; Žalud, Z.; Formayer, H.; Turňa, M.; Nejedlík, P.; et al. Drought trends over part of Central Europe between 1961 and 2014. *Clim. Res.* **2016**, *70*, 143–160. [CrossRef]
9. European Commission. *Communication from the Commission to the European Parliament and the Council: Sustainable Carbon Cycles*; COM(2021) 800 final; European Commission: Brussels, Belgium, 2021.
10. Csákvári, E.; Fabók, V.; Bartha, S.; Barta, Z.; Batáry, P.; Borics, G.; Botta-Dukát, Z.; Erős, T.; Gáspár, J.; Hideg, É.; et al. Conservation biology research priorities for 2050: A Central-Eastern European perspective. *Biol. Conserv.* **2021**, *264*, 109396. [CrossRef]
11. Kieft, H. Agricultural Sustainability. In *Central And Eastern Europe: Rural Production And Environment*; ETC Netherlands: Leusden, The Netherlands, 1999.
12. Nowicki, P.; Goba, V.; Knierim, A.; van Meijl, H.; Banse, M.; Delbaere, B.; Helming, J.; Hunke, P.; Jansson, K.; Terluin, I. *Scenar 2020-II—Update of Analysis of Prospects in the Scenar 2020 Study*; European Commission, Directorate-General Agriculture and Rural Development: Brussels, Belgium, 2009.
13. Kibblewhite, M.G.; Ritz, K.; Swift, M.J. Soil health in agricultural systems. *Phil. Trans. R. Soc. B.* **2008**, *363*, 685–701. [CrossRef]
14. Borrelli, P.; Paustian, K.; Panagos, P.; Jones, A.; Schütt, B.; Lugato, E. Effect of Good Agricultural and Environmental Conditions on erosion and soil organic carbon balance: A case study. *Land Use Policy* **2016**, *50*, 408–421. [CrossRef]

15. De Nocker, L.; Gobin, A.; Aertsens, J. Valuing the carbon sequestration potential for European agriculture. *Land Use Policy* **2013**, *31*, 584–594.
16. EEA. *Water Exploitation Index*; European Environment Agency: Copenhagen, Denmark, 2014. Available online: http://www.eea.europa.eu/data-and-maps/figures/water-exploitation-index-2014- (accessed on 21 September 2019).
17. EEA. *Annual European Union Greenhouse Gas Inventory 1990–2011 and Inventory Report 2013*; Submission to the UNFCCC Secretariat; EEA Technical Report 8/2013; EEA: Copenhagen, Denmark, 2013.
18. Flessa, H.; Müller, D.; Plassmann, K.; Osterburg, B.; Techen, A.-K.; Nitsch, H.; Nieberg, H.; Sanders, J.; Hartlage, O.M.Z.; Beckmann, E.; et al. *Studie zur Vorbereitung einer effizienten und gut abgestimmten Klimaschutzpolitik für den Agrarsektor*; Sonderheft 36. Special Issue vTI Agriculture and Forestry Research; Johann Heinrich von Thünen-Institut: Braunschweig, Germany, 2012.
19. Franzluebbers, A. Farming strategies to fuel bioenergy demands and facilitate essential soil services. *Geoderma* **2015**, *259–260*, 251–258. [CrossRef]
20. Kasimir-Klemedtsson, Å.; Klemedtsson, L.; Berglund, K.; Martikainen, P.; Silvola, J.; Oenema, O. Greenhouse gas emissions from farmed organic soils: A review. *Soil Use Manag.* **1997**, *13*, 245–250. [CrossRef]
21. Molina, J.; Crocker, G.; Grace, P.; Klír, J.; Körschens, M.; Poulton, P.; Richter, D. Simulating trends in soil organic carbon in long-term experiments using the NCSOIL and NCSWAP models. *Geoderma* **1997**, *81*, 91–107. [CrossRef]
22. Rabotayagov, S. Ecosystem services under benefit and cost uncertainty: An application to soil carbon sequestration. *Land Econ.* **2010**, *86*, 668–686. [CrossRef]
23. Rounsevell, M.; Freibauer, A.; Smith, P.; Verhagen, J. Carbon sequestration in the agricultural soils of Europe. *Geoderma* **2004**, *122*, 1–23.
24. EEA. *The European Environment State and Outlook 2010: Soil Thematic Assessment*; European Environment Agency: Copenhagen, Denmark, 2010.
25. Jaagus, J.; Aasa, A.; Aniskevich, S.; Boincean, B.; Bojariu, R.; Briede, A.; Danilovich, I.; Castro, F.; Dumitrescu, A.; Labuda, M.; et al. Long-term changes in drought indices in eastern and central Europe. *Int. J. Climatol.* **2022**, *42*, 225–249. [CrossRef]
26. Kubiak-Wójcicka, K.; Zeleňáková, M.; Pilarska, A. Influence of climate change on low flow conditions. Case study: Laborec River, eastern Slovakia. *Ecohydrol. Hydrobiol.* **2021**, *21*, 570–583. [CrossRef]
27. Kovář, S.; Kovařiček, P.; Novák, P.; Kroulík, M. The effect of soil tillage technologies on the surface of the infiltration speed of water into the soil. *Agron. Res.* **2016**, *14*, 434–441.
28. Lokoč, R. Motivations of Czech farmers with Regard to Reversion of Arable Land-Systems to Grassland. Veronica 5: 5-7. 2007. Available online: http://www.casopisveronica.cz/clanek.php?id=1267 (accessed on 21 September 2019).
29. Konečná, J.; Pražan, J.; Podhrázská, J.; Kučera, J.; Koutná, K.; Fiala, R. *Addressing Economic Aspects of Erosion Measures Regarding Agricultural Soils. Certified Methodology*; Research Institute of Melioration and Soil Conservation: Prague, Czech Republic, 2014.
30. Manchester, S.; McNally, S.; Treween, J.; Sparks, T.; Mountford, J. The cost and practicality of techniques for the reversion of arable land to lowland wet grassland—An experimental study and review. *J. Environ. Manag.* **1999**, *55*, 91–109. [CrossRef]
31. Ministry of Agriculture of the Czech Republic. *Rural Development Programme of the Czech Republic 2014–2020*; Ministry of Agriculture of the Czech Republic: Prague, Czech Republic, 2014.
32. Ministry of Agriculture of the Czech Republic. *Reversion of Arable Land-Systems to grassland. Agri-Environment-Climate Measures of the Rural Development Programme 2014–2020. Information Material for Farmers*, 2nd ed.; Ministry of Agriculture: Prague, Czech Republic, 2020.
33. Brtnicky, M.; Pecina, V.; Dokulilova, T.; Vopravil, J.; Khel, T.; Zloch, J.; Vlček, V. Assessment of retention potential and soil organic carbon density of agriculturally used chernozems, cambisols and Fluvisols. *Acta Univ. Agric. Silvic. Mendelianae Brun.* **2019**, *67*, 1131–1137. [CrossRef]
34. Stańczuk-Gałwiaczek, M. The implementation of Small Water Retention Programmes in Poland—Comparison of the current state with the state intended to obtain till year 2015. In Proceedings of the 18th International Multidisciplinary Scientific GeoConference SGEM2018, Albena, Bulgaria, 2–8 July 2018; Volume 18, pp. 725–731.
35. Kowalczyk, A.; Łabędzki, L.; Kuźniar, A.; Kostuch, M. An assessment of crop water deficits of the plants growing on the Małopolska Upland (Poland). *J. Water Land Dev.* **2016**, *29*, 11–22. [CrossRef]
36. Black, H.; Hart, K.; Poláková, J. *EU's Common Agricultural Policy and Climate Change Mitigation Actions: Literature Review*; Report Prepared for DG Climate Action, Contract No. 071303/2011/614488/SER/CLIMA.A2; Institute for European Environmental Policy: Brussels, Belgium; London, UK, 2012.
37. Janků, J.; Kosánová, M.; Kozák, J.; Herza, T.; Jehlička, J.; Maitah, M.; Vopravil, J.; Němeček, K.; Toth, D.; Jacko, K.; et al. Using of soil quality indicators to assess their production and ecological functions. *Soil Water Res.* **2022**, *17*, 45–58. [CrossRef]
38. Cooper, T.; Hart, K.; Baldock, D. *The Provision of Public Goods through Agriculture in the European Union*; Directorate-General Agriculture: Brussels, Belgium, 2009.
39. Prokopy, L.; Floress, K.; Klotthor-Weinkauf, D.; Baumgart-Get, A. Determinants of agricultural best management practice adoption: Evidence from the literature. *J. Soil Water Conserv.* **2008**, *63*, 300–311. [CrossRef]
40. Pullin, A.; Báldi, A.; Emrecan, O.; Dieterich, M.; Kati, V.; Mihók, B.; Sousa-Pinto, N. Conservation focus on Europe: Major conservation policy issues that need to be informed by conservation science. *Conserv. Biol.* **2009**, *23*, 818–824. [CrossRef]

41. Zellei, A.; Gorton, M.; Lowe, P. Agri-environmental policy systems in transition: Problems and perspectives. In *Sustainable Agriculture in Central and Eastern European Countries: The Environmental Effects of Transition and Needs for Change*; Gatzweiler, F., Hagedorn, K., Judis, R., Eds.; Shaker Verlag: Aachen, Germany, 2002.
42. Frelih-Larsen, A.; Leprand, A.; Naumann, S.; Beucher, O. *Deliverable D11 Climate Mitigation through Agricultural Techniques*; Piccmat Report. FP6 Framework Project; European Commission: Brussels, Belgium, 2008.
43. Prager, K.; Nagel, U. Participatory decision mak ing on agri-environmental programmes: A case study from Sachsen. *Land Use Policy* **2008**, *25*, 106–115. [CrossRef]
44. Visser, M.; Morana, J.; Regana, E.; Gormally, M.; Sheehy Skeffington, M. The Irish agri-environment: How turlough users and non-users view converging EU agendas of Natura 2000 and CAP. *Land Use Policy* **2007**, *24*, 362–373. [CrossRef]
45. Thorsøe, M.H.; Andersen, M.S.; Brady, M.V.; Graversgaard, M.; Kilis, E.; Pedersen, A.B.; Pitzén, S.; Valve, H. Promise and performance of agricultural nutrient management policy: Lessons from the Baltic Sea. *Ambio* **2021**, *51*, 36–50. [CrossRef]
46. Kessler, A.; De Graaff, J.; Olsen, P. Farm-level adoption of soil and water conservation measures and policy implications in Europe. *Land Use Policy* **2010**, *27*, 1–3.
47. European Commission. *Rural Development Programmes: Country Files*; European Commission: Prague, Czech Republic, 2015.
48. Trnka, M.; Kyselý, J.; Možný, M.; Dubrovský, M. Changes in central-European soil-moisture availability and circulation patterns in 1881–2005. *Int. J. Climatol.* **2009**, *29*, 655–672. [CrossRef]
49. Trnka, M.; Olesen, J.; Kersebaum, K.; Skjelvag, A.; Eitzinger, J.; Seguin, B.; Peltonen-Sainio, P.; Rotter, R.; Iglesias, A.; Orlandini, S.; et al. Agroclimatic conditions in Europe under climate change. *Glob. Change Biol.* **2011**, *17*, 2298–2318. [CrossRef]
50. Van-Camp, L.; Bujarrabal, B.; Gentile, A.; Jones, R.; Montanarella, L.; Olazabal, C.; Selvaradjou, S. *Volume III Organic matter and Biodiversity*; Reports of the technical work groups established under the Thematic Strategy for Soil Protection. E21319; European Soil Data Centre (ESDAC): Ispra, Italy, 2004.
51. Cooper, T.; Baldock, D.; Rayment, M.; Kuhmonen, T.; Terluin, I.; Swales, V.; Poux, X.; Zakeossian, D.; Farmer, M. *An Evaluation of the Less Favoured Area Measure in the 25 Member States of the European Union*; Report for Directorate-General Agriculture; European Commission: Brussels, Belgium, 2006.
52. Jezierska-Thöle, A.; Gwiaździńska-Goraj, M.; Biczkowski, M.; Rudnicki, R.; Wiśniewski, L. The agri-environment-climate measure as an element of the bioeconomy in Poland—A spatial study. *Agronomy* **2020**, *11*, 110. [CrossRef]
53. Bartlová, J.; Badalíková, B.; Pospíšilová, L.; Pokorný, E.; Šarapatka, B. Water stability of soil aggregates according to systems of tillage. *Soil Water Res.* **2015**, *10*, 147–154. [CrossRef]
54. Žížala, D.; Minařík, R.; Beitlerová, H.; Juřicová, A.; Skála, J.; Rojas, J.; Penížek, V.; Zádorová, T. High-Resolution Soil Property Maps from Digital Soil Mapping Methods, Czech Republic. Available online: https://ssrn.com/abstract=3928321 (accessed on 21 February 2022).
55. Kavka, M. *Farm Management Pocketbook*, 28th ed.; Kapos Consultants Ltd.: Prague, Czech Republic, 2018.
56. van der Ploeg, J.D.; Barjolle, D.; Brunori, G.; Brunori, G.; Madureira, L.M.C.; Dessein, J.; Drąg, Z.; Fink-Kessler, A.; Gasselin, P.; de Molina, M.G.; et al. The economic potential of agroecology: Empirical evidence from Europe. *J. Rural. Stud.* **2020**, *71*, 46–61. [CrossRef]
57. Poláková, J.; Berman, S.; Naumann, S.; Frelih-Larsen, A.; von Toggenburg, J.; Farmer, A.; in collaboration with BIO Intelligence Service and Ecologic Institute. *The Sustainable Management of Natural Resources with a Focus on Water Management and Agriculture; Report to the STOA Committee of the European Parliament*; Institute for European Environmental Policy (IEEP): London, UK; Brussels, Belgium, 2012.
58. Pelucha, M.; Kveton, V.; Safr, K. Theory and reality of the EU's rural development policy application in the context of territorial cohesion perspective—The case of the Czech Republic in the long-term period of 2004–2013. *Land Use Policy* **2017**, *62*, 13–28. [CrossRef]
59. Loriz-Hoffmann, J. *Vorschlaege der Kommission fur die Laendliche Entwicklungspolitik nach 2013*; Directorate-General Agriculture: Lambach, Austria, 2011.
60. Kastner, T.; Chaudhary, A.; Gingrich, S.; Marques, A.; Persson, M.; Bidoglio, G.; Le Provost, G.; Schwarzmüller, F. Global agricultural trade and land system sustainability: Implications for ecosystem carbon storage, biodiversity, and human nutrition. *One Earth* **2021**, *4*, 1425–1443. [CrossRef]
61. Vávra, J.; Duží, B.; Lapka, M.; Cudlínová, E.; Sanford Rikoon, J. Socio-economic context of soil erosion: A comparative local stakeholders' case study from traditional agricultural region in the Czech Republic. *Land Use Policy* **2019**, *84*, 127–137. [CrossRef]
62. Janků, J.; Jehlička, J.; Heřmanová, K.; Toth, D.; Maitah, M.; Kozák, J.; Vopravil, J.; Vácha, R.; Jacko, K.; Herza, T. An overview of a land evaluation in the context of ecosystem services. *Soil Water Res.* **2022**, *17*, 1–14. [CrossRef]
63. OECD. Design and Implementation of Agri-Environmental Policies: Are Guidelines Feasible? In *Evaluation of Agri-Environmental Policies: Selected Methodological Issues and Case Studies*; OECD Publishing: Paris, France, 2012.
64. Biney, J.; Vašát, R.; Bell, S.; Kebonye, N.; Klement, A.; John, K.; Borůvka, L. Prediction of topsoil organic carbon content with Sentinel-2 imagery and spectroscopic measurements under different conditions using an ensemble model approach with multiple pre-treatment combinations. *Soil Tillage Res.* **2022**, *220*, 105379. [CrossRef]
65. Wiltshire, J. *Assessment of the Effectiveness, Impact and Cost of Measures to Protect Soils*; Ricardo-AEA Ltd.: Didcot, UK, 2013.
66. Pimentel, D.; Harvey, C.; Resosudarmo, P.; Sinclair, K.; Kurz, D.; McNair, M.; Crist, S.; Shpritz, L.; Fitton, L.; Saffouri, R.; et al. Environmental and Economic Costs of Soil Erosion and Conservation Benefits. *Science* **1995**, *267*, 1117–1123. [CrossRef] [PubMed]

67. Kuhlman, T.; Reinhard, S.; Gaaff, A. Estimating the costs and benefits of soil conservation in Europe. *Land Use Policy* **2010**, *27*, 22–32. [CrossRef]
68. Frelih-Larsen, A.; Bowyer, C.; Albrecht, S.; Keenleyside, C.; Kemper, M.; Nanni, S.; Naumann, S.; Mottershead, R.; Landgrebe, R.; Sarapatka, B.; et al. *Soil Inventory. 'Updated Inventory and Assessment of Soil Protection Policy Instruments in EU Member States'*; Report to the European Commission; Ecologic Institute: Berlin, Germany, 2017.
69. Debicki, R.; Lipiec, B.; Krasowicz, S. Poland. *J. Soil Water Conserv.* **2004**, *59*, 38–39.
70. Souza Krupek, F.; Redfearn, D.; Eskridge, K.; Basche, A. Ecological intensification with soil health practices demonstrates positive impacts on multiple soil properties: A large-scale farmer-led experiment. *Geoderma* **2022**, *409*, 115594. [CrossRef]
71. Wauters, E.; Bielders, C.; Poesen, J.; Govers, G.; Mathijs, E. Adoption of soil conservation practices in Belgium: An examination of the theory of planned behaviour in the agri-environmental domain. *Land Use Policy* **2010**, *27*, 86–94. [CrossRef]
72. Kadlec, V.; Žížala, D.; Novotný, I.; Heřmanovská, D.; Kapička, J.; Tippl, M. Land consolidations as an effective instrument in soil conservation. *Ekológia* **2014**, *33*, 188–200. [CrossRef]
73. Dabkiene, V.; Balezentis, T.; Streimikiene, D. Development of agri-environmental footprint indicator: Tracking development of sustainable agricultural development in Eastern Europe. *Sustain. Prod. Consum.* **2021**, *27*, 2121–2133. [CrossRef]
74. European Parliament. How the CAP can improve rural jobs. In *Policy Department Structural and Cohesion Policies*; European Parliament: Brussels, Belgium, 2016.
75. Ostle, N.J.; Levy, P.E.; Evans, C.D.; Smith, P. UK land use and soil carbon sequestration. *Land Use Policy* **2009**, *26*, 274–283. [CrossRef]
76. Burrell, A. Chapter 2—Evaluating policies for delivering agri-environmental public goods. In *Evaluation of Agri-Environmental Policies: Selected Methodological Issues and Case Studies*; OECD Publishing: Paris, France, 2012.
77. Gross, M. The paradoxical evolution of agriculture. *Curr. Biol.* **2013**, *23*, R667–R670. [CrossRef]
78. Novak, P.; Vopravil, J.; Lagova, J. Assessment of the soil quality as a complex of productive and environmental soil function potentials. *Soil Water Res.* **2010**, *5*, 113–119. [CrossRef]
79. Larramendy, M.; Soloneski, S.; Menšík, L.; Hlisnikovsky, L.; Kunzová, E. The state of the soil organic matter and nutrients in the long-term field experiments with application of organic and mineral fertilizers in different soil-climate conditions in the view of expecting climate change. In *Organic Fertilizers: History, Production and Applications*; Larramendy, M., Soloneski, S., Eds.; IntechOpen: London, UK, 2019; pp. 1–29.
80. Underwood, E.; Baldock, D.; Aiking, H.; Buckwell, A.; Dooley, E.; Frelih-Larsen, A.; Naumann, S.; O'Connor, C.; Poláková, J.; Tucker, G. *Technology Options for Feeding 10 Billion People. Climate Change and Agriculture*; Biodiversity and Agriculture; Report prepared to the STOA Panel of the European Parliament; Institute for European Environmental Policy: London, UK; Brussels, Belgium, 2013.
81. Chabé-Ferret, S.; Subervie, J. Chapter 10—Econometric methods for estimating the additional effects of agri-environmental schemes on farmers' practices. In *Evaluation of Agri-Environmental Policies: Selected Methodological Issues and Case Studies*; OECD Publishing: Paris, France, 2012.
82. Poppe, K.; van Doorn, A. *Options to Redesign the European Agricultural Policy after 2020*; LEI-Report 2016-009; LEI: Wageningen, The Netherlands, 2016.
83. Pajewski, T.; Malak-Rawlikowska, A.; Gołębiewska, B. Measuring regional diversification of environmental externalities in agriculture and the effectiveness of their reduction by EU agri-environmental programs in Poland. *J. Clean. Prod.* **2020**, *276*, 123013. [CrossRef]