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Review

Strategies of Climate Change Mitigation in Agriculture Plant Production—A Critical Review

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Abstract: Agriculture is the second-highest, after energy use, source of greenhouse gas emissions, which are released from soils and animal digestion processes and as a result of energy consumption at various stages of agricultural production. However, changes in the management of agricultural systems may mitigate the negative impact of this sector on the atmosphere and climate. This paper presents a literature review on energy consumption in agriculture and the potential of agricultural crop production to assist in mitigation of global warming by increasing absorption of CO_2 from the atmosphere. The issue was considered in the context of managing the cultivation of main, catch and cover crops. The potential of carbon sequestration in the above- and below-ground biomass of selected crops was analyzed. It was stated that, depending on the species, main crops can sequester up to 113 CO_2 ha^{-1} yr^{-1} in whole biomass, while catch or cover crops can sequester up to 14.80 CO_2 ha^{-1} yr^{-1} and 0.17 CO_2 ha^{-1} yr^{-1} in the above- and below-ground biomass, respectively. The benefits of the spread of catch or cover crops, such as improvement of soil quality (leading to an increase in primary crop yield by even as much as 65%) and a phytosanitary effect, as well as the barriers that limit the use of catch crops, including the problems with matching crop species to climate and soil conditions and the risk of reducing farmers' income, were considered. The results of the review show that catch crops can assimilate an additional amount of 4 to 6 tonnes CO_2 ha^{-1} yr^{-1}, and thus, spreading of catch crops is an effective way to reduce the climate impact of agriculture.

Keywords: energy consumption; plant production; main crops; catch crops; carbon farming; climate change; carbon sequestration; soil organic carbon

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1. Introduction

Conversion of solar energy into chemical energy of biomass through photosynthesis is the basis of agricultural production. However, modern agriculture is aimed at achieving large and fast biomass yields, which requires additional energy inputs, both at the stage of crop production itself (i.e., during land preparation, irrigation, fertilization, sowing/planting, crop care and harvesting), as well as during animal production (e.g., space heating and providing feed and water). Energy is also needed during transportation, storage and processing of agricultural products into food products. In addition, energy is consumed in the production of mineral fertilizers, crop protection products and medicines for livestock.

Energy consumption in agriculture varies significantly depending on the nature of the crop and location. The review of energy consumption in production of selected crops in 49 countries worldwide made by Kargwal et al. [1] showed that the values of direct and indirect energy consumption for various crops' production were as follows: wheat—10,900 MJ ha^{-1} (Australia) to 35,737 MJ ha^{-1} (Turkey); rice—12,800 MJ ha^{-1} (Philippines) to 64,158 MJ ha^{-1} (Iran); and millet 3283 MJ ha^{-1} (Nigeria) to 7000 MJ ha^{-1} (India).

Most of the energy required to meet the needs of agriculture still comes from non-renewable sources [2–4], although the share of renewable energy in total energy consumption in agriculture is gradually increasing, as indicated by studies conducted between 2005 and 2018 in EU countries [4].

One disadvantageous effect of energy consumption for agricultural production is the emission of greenhouse gases (GHGs). However, the results of global estimates show that the contribution of this aspect in the widely-understood agriculture, a category that includes also the forestry and other land use (AFOLU) sector, is relatively small compared to that of the emissions from soils and animal husbandry, mainly cattle. It is estimated that AFOLU corresponds to 18.4% of total GHG emissions (9.2 billion tonnes CO_2 eq.), which, in 2020, approximated 49.9 billion tons of CO_2 eq. Emissions in the agriculture-related sector consist of: livestock and manure (5.8%), agricultural soil (4.8%), crop burning (3.5%), rice cultivation (1.3%), deforestation (2.2%), cropland (1.4%) and grassland (0.1%). In terms of contribution to total emissions, AFOLU is comparable to transportation (16.2% of total emissions) and energy use in buildings (17.5%), and slightly behind the energy use in industry (24.2%). In addition to the emissions from the agricultural sector, the emissions from energy use in agriculture and fishing can be added, which are estimated at 1.7%, corresponding to 0.85 billion tonnes CO_2 eq. (data source: Climate Watch and the World Resources Institute on the basis of 5th Assessment Report of IPCC, given by Our World in Data 1.). [5]. Flammini et al. [6] have found increased rates of annual emissions from energy use in agriculture amounting to 1.029 billion tonnes CO_2 eq yr^{-1}, including electricity. Without the electricity, it was ca. 0.523 billion tonnes CO_2 eq yr^{-1}.

Unlike the energy sector, which releases mainly CO_2, agriculture is primarily a source of methane and nitrous oxide. Emissions of these gases account for about 60% of GHG emissions from AFOLU, while livestock production is responsible for 2/3 of this value [7]. Livestock production has been steadily increasing for many years. Between 2000 and 2018, it increased from 232 mln tonnes to 342 mln tonnes. In 2020, there was a slight decrease in production to 337 mln tonnes, but in 2021, production had already increased to 340 mln tonnes. Due to increasing demand for animal products, it is predicted that the GHG emissions from the meat industry will rise 9% by 2031 [8], which could increase GHG emissions, especially methane. The global warming potential (GWP) of this gas, calculated on a 100-year scale, is 27–30 [9]. Reducing GHG emissions in the meat industry is difficult, although Ocko et al. [10] estimate that deploying all economically feasible livestock abatement strategies, such as inhibitors of methanogenesis and improving manure management would allow the avoidance of nearly 0.1 °C of global-mean warming in 2100.

According to FAO data [7], in 2018, agriculture and land use emissions were equal to 9.3 billion tonnes CO_2 eq. and accounted for 17% of global GHG emissions. However, the sector's share has significantly decreased compared to 2000, when it was estimated at 24%. Nevertheless, this decrease is mainly due to an increase in emissions from other sectors of the economy, as the emissions from agriculture have remained relatively constant over the years. In 2000 they amounted to 9.6 billion tonnes CO_2 eq. In comparison, the emissions from fuel combustion between 2000 and 2018 rose from 23.7 billion tonnes CO_2 to 34.32 billion tonnes CO_2 eq. [11].

The cumulative energy consumption in the EU in 2020 was 37,086 PJ [12] of which agriculture consumed about 3% [13], or 1112.58 PJ. According to Eurostat [3], 56% of the energy consumed in agriculture in 2020 in the EU countries, i.e., approximately 623.05 PJ, originated from the combustion of fossil fuels.

The unfavorable climate changes recently affecting various parts of the world oblige governments to set ambitious climate policy goals. In 2015, representatives of countries attending the UN Climate Change Conference (COP21) signed the Paris Agreement, pledging to take action to ensure a peak of global greenhouse gas emissions before 2025. Next, the emissions should be reduced by 43% by 2030. The estimations made by Costa et al. [14] showed that changes in food systems can reduce GHG emissions from this sector by 90%, but in their opinion, the goals of Paris Agreement can only be achieved by including

modifications in agriculture production and the human diet, reducing the amount of food waste and strengthening food security and safety. One of the ways to bring the Paris commitments closer to realization is to make changes in the economy by transitioning to its low-carbon variant. The development of such an economy requires the integration of the activities of low-carbon technologies and practices, efficient energy solutions, clean and renewable energy and environmentally friendly technological innovations [15,16]. Rural areas, including farmlands, and especially the crop production sector, can play a large role in the low-carbon economy. The priority of farming, which includes the goals of such an economy, is to obtain the most favorable carbon balance, as a result of CO_2 sequestration by above- and below-ground parts of plants, and to "store" carbon in the soil for as long as possible, as a result of its incorporation into humic compounds. Soil under crops becomes a kind of "carbon sink", thereby reducing the concentration of carbon dioxide in the atmosphere [17–20].

Carbon farming is closely linked to soil quality. Carbon converted to organic form in the soil stimulates the activity of soil enzymes, promotes the growth of beneficial microorganisms and improves chemical and physicochemical properties, including pH, sorption capacity and water retention. Studies indicate that the carbon sequestration capacity of soil depends on many factors, including soil grain size. Heavy, finely-grained soils have a higher sequestration capacity than do coarsely-grained soils, so when evaluating the potential of soils as a "sink" for carbon, this aspect should be taken into account. In addition, the efficiency of the soil in terms of carbon storage is determined by the yield of biomass obtained on it and the related amount of organic matter that is an external source of carbon. Thus, it is important to properly select plant species and balance fertilization [21–23].

The move toward a low-carbon economy in agriculture is linked to changes in the animal food production system and human food habits. Demand for beef is very high in many countries, especially in highly-developed ones [24]. This raises concerns about the impact of cattle farming on climate change [25,26]. Beef and dairy production account for more than 70% of GHG emissions from livestock farming, which collectively emit ca. 6.3 Gt CO_2 eq yr^{-1} [27]. The findings of Cusak et al. [28] indicate that net GHG emissions from livestock farming can be significantly reduced through changes in farm management. The research revealed that application of site-utilizing carbon (C) sequestration management on grazed lands achieved a 46% reduction in net GHG emissions per unit of beef, while sites using growth efficiency strategies achieved an 8% reduction. However, only 2% of studies achieved net-zero emissions. At the same time, these data show how difficult it can be for carbon agriculture to offset the GHG emissions from livestock production.

A much more real potential for increasing CO_2 sequestration from the atmosphere and decreasing the emissions originating from agriculture is seen in crop production. Plants are natural absorbers of CO_2, in which the atmospheric CO_2 is integrated into the plant biomass due to photosynthesis. Chlorophyll is the "factory" where CO_2 is converted into organic compounds by using the radiant energy of sunlight. The solar radiation is used to produce energy molecules, such as NADPH and ATP, from NADP+ and ADP. The dark reactions involve the Calvin–Benson cycle, which takes place late in the process, using the energy molecules produced in the light reactions. On the basis of the adaptation to photosynthesis and various mechanisms involved in the processes of carbon fixation, the plants are classified into C3, C4 and CAM [29]. Depending on the mechanism of carbon fixation, the efficiency of this process varies. In C4 plants, photorespiration is reduced by increased CO_2 concentration at the RuBisCo (the enzyme ribulose bisphosphate carboxylase/oxygenase) activation site. Oxygenase is inhibited, and CO_2 is incorporated in the bundle sheath and mesophyll present in the leaf. Due to this mechanism, the conversion efficiency of C3 plants is lower than C4 [30]. The Crassulacean acid metabolism (CAM) pathway is a very efficient way of C sequestration which helps plants to survive in the dry ecosystem and drought season [31].

Given the natural carbon-fixing capacity of plants, several options for improving CO_2-absorbing capacity and reducing emissions of GHGs in agricultural crop production

are being considered. One way is to increase the production of plant biomass in agricultural crops, both the main crop and catch/cover crops. The biomass of the latter is a source of soil humus, which is a long-term carbon store due to its resistance to biodegradation. Such a solution is closely related to carbon farming and enables the low-carbon development of agricultural regions. Additionally, the use of intercrops, in addition to the environmental benefits of improving air and soil quality, is associated with obtaining an increase in the yield of the main crop, as a result of increasing soil fertility as well as reducing the occurrence of weeds and fungal diseases in agrocenoses, which brings economic benefits. In addition, it is possible to obtain subsidies for intercropping from European Union funds [32–35].

The issue of the relationship between agriculture and climate change has been the subject of scientific discussion for several decades. The problem was noticed in the second half of the 20th century. Initially, considerations focused on the impact of climate change on agriculture and the possibilities of adapting food of production systems to these changes [36,37]. The dependence of climate on agriculture only began to be recognized in the 1970s [38], although research was still focused on the consequences of climate change in agriculture [39–41]. The deeper insights into the issue of mitigation of climate change by agriculture were provided by Paustian et al. [42,43]. Reviewing the literature at the time, they concluded that mitigation options in this sector could be divided into two categories: increasing stocks of organic C, and reducing of fossil C consumption.

Within the last 20 years, the knowledge of the relationships between climate and agriculture has been extended so much that particular review papers have focused on the selected problems. The key issues include the impacts of farming practices and systems on soil carbon sequestration [44–48], changes in farming practices, including animal diet modification and manure management [45] and land use change and agroforestry [46,49,50].

In addition to the impact of agriculture on CO_2 emissions, attention has also been paid to the emissions of N_2O [51–54]) and CH_4 [54–57] as important GHGs, and opportunities of reducing their emissions. Other ways of mitigating climate change in agriculture, which have been discussed in the review papers published in recent years, is biochar addition to the soil [58–60]. Additionally, attention was drawn to the role of crops in increasing carbon sequestration and reducing the impact on GHG emissions. In this regard, the significance of catch or cover crops has been emphasized. These crops can improve the soil quality and contribute to increasing the yield of main crops [61], especially when considering their underground biomass [62]. Additionally, the crop biomass may be utilized as a feedstock to produce biofuels [63].

The aim of this paper is to analyze the state of knowledge on the possibility of reducing GHG emissions from the agricultural sector via modifications in plant production systems, and to estimate the potential effects of these activities. The data on the main catch and cover crop yields, those typical for farming in European countries, were analyzed in terms of net carbon sequestration and the potential offset of CO_2 emissions released as results of burning the fossil fuels used for energy production in the agricultural sector.

2. Materials and Methods

The source materials used in the study came from these databases: Scopus, Web of Science, Google Scholar, Science Direct, SpringerLink and Wiley, as well as databases of European legislation, studies and reports of international NGOs (e.g., Eurostat, International Energy Agency (IEA), the Food and Agriculture Organization (FAO) and the European Environmental Agency (EEA)) and national institutions (e.g., US Environmental Protection Agency and The National Centre for Emissions Management, Poland). The analyses took into account information derived mainly from the last few years. Earlier data sources were used only when substantively justified.

When selecting the papers included in the review, the choice was guided primarily by their substantive relation to a particular chapter (by entering combinations of several main keywords, i.e., agriculture, energy consumption, greenhouse gas emission, food system,

carbon farming, soil carbon, sequestration, and yield + names of main/catch crops selected as typical for different regions of the world) pertaining to the main content of the chapter. Additional keywords were used to find information supplementing the data or explaining the given phenomenon or process. The selection of sources was guided by the relevance of the knowledge, especially in the case of issues related to carbon farming and soil carbon sequestration. These issues have started to be analyzed more thoroughly only in the last 5 years. In the case of comparisons of the yields of individual crops, efforts were also made to seek information from recent years. However, up-to-date information for some crops was not always available, and hence, older data was cited in several cases. Older papers were also cited when time-dependent changes in the data were analyzed or when describing the processes of the mechanisms that had been explained earlier. The largest number of source items (ca. 50% of all references) was used when discussing yields of major crops' catch and cover crops, followed by works on energy consumption and greenhouse gas emissions in agriculture (ca. 27%), carbon sequestration in soil (ca. 15%) and carbon farming (ca. 8%).

3. Carbon Farming—The Fundament of Reducing GHG Emissions from Agricultural Production

Carbon farming, as an agriculture practice enabling the production of food and related items in a sustainable manner, has received widespread attention in recent years [64]. Generally, carbon farming is aimed at enhancing the removal rate of the CO_2 in the atmosphere as well as its conversion into plant biomass and soil organic matter (SOM). This improves soil fertility and promotes crop productivity, increasing the potential of long-term carbon storage, which leads to reducing GHG concentrations in the atmosphere.

Implementation of the objectives laid down in the Sustainable Carbon Cycle Communication of December 2021 and the Regulatory Framework for the Certification of Carbon Removals of November 2022 will be made possible by, inter alia, developing carbon farming in the EU. The Fit for 55 package, a part of European Commission's law actions for the climate adopted in July and December 2021, indicates an increasing role for agriculture and land use in delivering on climate mitigation objectives, increasing removal targets for 2026–2030, aiming for a climate neutral agriculture, land use and forestry sector by 2035 and increasing environmental monitoring requirements. Carbon farming focuses on the management of carbon pools, flows and GHG fluxes at the level of particular farms. This involves actions concerning both plant cultivation and livestock, which are directed towards carbon retention in soils and biomass, as well as reducing fluxes of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in agriculture [65,66]. For land managers, this definition means that carbon farming includes agricultural practices and land use changes that achieve one or more of the following outcomes: (1) sequestering carbon and storing it in agricultural soils or biomass above and below ground; (2) preventing future CO_2 and other greenhouse gas emissions; and (3) reducing existing CO_2 and other greenhouse gas emissions [67].

There is no one universal approach to effective carbon farming. Effective farming includes both agronomic practices connected with land use changes as well as technological solutions. Five main carbon farming interventions are indicated: (1) peatland rewetting and restoration; (2) agroforestry system establishment and maintenance; (3) maintenance and enhancement of soil organic carbon (SOC) on mineral soils; (4) livestock and manure management; and (5) nutrient management on croplands and grasslands [65]. Different mitigation measures are suitable for different types of farming activities and regions [67]. The tactics mostly used are traditional tillage, more efficient fertilizer use, biofertilizers use, no-till farming, mulching, cover crops, improved crops rotations, land-use change, peatland restoration, expanding agroforestry systems, and shifts in type and location of production [47,64,68,69]. Selection of the appropriate crops is essential to obtain the effect of carbon sequestration. These crops should have the following features: high photosynthetic power of plants, increased below-ground carbon allocation, interactions

with a soil microbiome, and enhanced plant-growth-promoting (PGP) properties that facilitate nutrient acquisition and water-use efficiency [70,71].

Tang et al. [72] estimated that in the case of farms from China's Loess Plateau, where crop rotation had been applied as the only practice that could reduce on-farm greenhouse gas emission, the emissions were reduced of 16.6 and 33%, with marginal abatement costs. Studies of the environmental impact of eggplant (*Solanum melongena*) cultivation conducted in Greece indicate that organic cultivation without using pesticides and mineral fertilizers exhibited 24.15% lower total environmental footprint compared to conventional cultivation [73]. A higher potential of carbon footprint reduction was estimated in the case of fruit trees in Mediterranean countries. According to the LCA analysis conducted by Aguilera et al. [74], organic cropping based on using biofertilizers and energy recovery from residual wood can lead to 56% decrease of GHG emissions compared to conventional cropping, when calculated on a per-area basis, and 39% decrease when calculated on a product basis.

Besides the mitigation of climate change, carbon farming often delivers additional environmental or economic benefits, such as protection of biodiversity or cost savings to farmers [72,75]. It can deliver many co-benefits for the environment and the sustainability of agriculture, e.g., an increase in crop resilience against climate impacts and improved stability of yields, as well as more efficient use of crop nutrients and livestock feeding regimes. Additionally, development of technological options, such biogas production from agricultural waste, changes in livestock housing and using nitrification inhibitors can also reduce GHG emission intensity per unit of output and improve resource efficiency [48,76,77]. However, some measures that are effective for mitigating climate change can negatively affect other environmental or societal objectives, for example, soil health or animal welfare. Decreased agricultural output due to implementation of some practices connected with the changes of land use or agricultural systems can be observed [21,76,78]. A trend in reducing the amount of roughage in animal forage can lead to digestive problems for the cattle. Additionally, forage additives, such as fumarate, nitrates and sulfates, which inhibit CH_4 production due to biomass digestion in cattle rumen, can interfere with the normal functioning of animal bodies [79].

However, an important premise for the development of carbon farming is economics. Farmers will be interested in the implementation of the practices that reduce GHG emissions or sequester carbon, if these will be associated with increasing income, or at least will not generate losses. Thus, the term "carbon farming" can also refer to a new business agriculture model, one which is based on incentives for farmers to take up the farming practices that deliver climate benefits at the farm level. Public funds, private payments or a combination of these two sources can be used for these incentives. Carbon farming is funded within The Common Agricultural Policy (CAP) mainly through co-financing the Second Pillar "Rural Development Policy" which is focused on supporting the rural areas' efforts to meet the economic, environmental and societal challenges of the 21st century. The first CAP has been criticized for insufficiently addressing the environmental goals tending towards reduction of carbon emission. Thus, the new CAP obliges the UE countries to identify and prioritize climate needs in their national CAP Strategic Plans. It gives them different opportunities to support the spreading of effective carbon farming practices with involvement of EU or national funds, both within the first Pillar, which covers direct supports for farmers, and the second Pillar, which covers rural development [80]. Financial support for the farmers who want to contribute to improving the quality of the environment can also be provided by private entities. Transfers of private funds can be realized by the supply chain for agricultural products, such as mark-ups to product prices or via carbon markets [65,79,81].

Changing the cropping system as a result of implementing the principles of carbon farming can become one of the sources of farm income. As part of the implementation of the Common Agricultural Policy (CAP) of EU countries from 2023, farmers who have switched to low-carbon farming will be able to seek compensation for the costs of the changes made. The amount of compensation will depend on the type of practices implemented on the

farm which lead to the advantage of carbon sequestration rather than its release into the atmosphere via plant respiration and soil emissions. The usage of nitrogen fixing and catch crops, the adoption of a fertilization plan appropriate to the soil type and crop needs, and a diversified crop structure are among the practices that can be implemented. Certification of farms converting to low-carbon farming is anticipated [82,83].

Taking into account the increasing demand for food products and its subsequent environmental impact, sustainable practices in agriculture should be prompted and encouraged. It is possible to mitigate the dependence of the agricultural output on climate change via less intensive and properly selected farming methods, ones which allow controlling the sensitive balance between the climate and agricultural systems. Low-carbon farming constitutes a sustainable and comprehensive method for managing land use, which is advantageous both for society and the environment [64].

4. Crop Biomass versus Carbon Sequestration

Multifunctional systems, such as mixtures of multiple species, tree cropping on cropland, and the use of perennial plant species, have been shown to create complex ecosystem structures that sequester carbon, support biodiversity and deliver ecosystem services to the surrounding agricultural land [84–86]. Perennial crops have the potential to capture and hold large quantities of SOC. Paustian et al. [42] and Boody et al. [84] report that, for example, in Minnesota, up to 0.9 Mg of carbon per ha per year can be accumulated. The modeled scenario of increased vegetation cover in a single Minnesota catchment showed that soil organic content increased by 86% as more grasslands and riparian buffers were established. Toensmeier et al. [87] point to the potential of perennial vegetables in increasing the share of the agricultural sector in carbon sequestration. They found that there are 613 cultivated perennial vegetables in the world, which represent 107 botanical families, and estimated that a wider use of these vegetables would enable the assimilation of 22.7–280.6 million tonnes of CO_2 eq yr^{-1}.

The potential for increasing soil-carbon accumulation is also associated with changes in the selection of main crops in agroecosystems. Previous research by different authors (Table 1) indicated that the scale of CO_2 sequestration in the biomass of main crop plants such as selected cereals, root crops and oilseeds varies over a wide range. Crop diversification that takes into account a rational crop rotation can increase the photosynthetic C uptake and gross primary productivity (GPP) of biomass in a given area.

Table 1. Primary and secondary yield of biomass (dry weight) and CO_2 sequestration of selected main crops.

Crops	Primary Yield: Grain/Seeds, Roots, Tubers, Biomass * (t ha^{-1})	Secondary Yield: Straw, Stems, Leaves (t ha^{-1})	Below-Ground Crop Residues/Roots (t ha^{-1})	Total Carbon Sequestration in Biomass of Primary, Secondary Yield and Roots (t CO_2 ha^{-1} yr^{-1})	Additional Data
1	2	3	4	5	6
Winter wheat	6.36 [88]	4.22 [88]	0.12 [88]	16.6 [88]	Poland
	6.5 [89]	4.31	0.15	16.09	Average value
	4.8 [90]	3.18	0.11	11.88	Average value
Spring wheat	5.57 [88]	3.94 [88]	0.11 [88]	14.9 [88]	Poland
	4.50 [91]	2.98	0.12	12.0	Russia
	6.30 [92]	4.18	0.15	16.8	China

Table 1. *Cont.*

Crops	Primary Yield: Grain/Seeds, Roots, Tubers, Biomass * (t ha^{-1})	Secondary Yield: Straw, Stems, Leaves (t ha^{-1})	Below-Ground Crop Residues/Roots (t ha^{-1})	Total Carbon Sequestration in Biomass of Primary, Secondary Yield and Roots (t CO_2 ha^{-1} yr^{-1})	Additional Data
1	2	3	4	5	6
Spring barley	4.10 [93]	2.84	0.08	10.8	Denmark
	5.34 [88]	3.70 [88]	0.10 [88]	14.1 [88]	Poland
	6.40 [94]	4.43	0.12	16.9	Germany
	6.67 [95]	4.62	0.12	17.6	Czech Republic
Winter rye	4.51 [88]	3.65 [88]	0.13 [88]	12.9 [88]	Poland
	2.44 [96]	1.61	0.12	6.9	Russia
	5.50 [97]	4.45	0.17	15.6	Uzbekistan
Oats	4.03 [88]	3.26 [88]	0.09 [88]	11.5 [88]	Poland
	5.38 [98]	4.35	0.14	15.3	Romania
	3.98 [99]	3.21	0.11	11.3	Turkey
Maize	8.39 [88]	4.12 [88]	0.45 [88]	20.2 [88]	Poland
	5.70 [100]	2.8	0.45	13.7	Ethiopia
	5.79 [101]	2.8	0.31	21.6	Indonesia
	18.75 [102]	9.2	1.00	45.0	China
Proso millet	3.33 [88]	2.17 [88]	0.06 [88]	8.66 [88]	Poland
	1.98 [103]	1.29	0.05	5.14	Italy
	2.60 [104]	1.70	0.07	6.76	USA
	2.63 [105]	1.75	0.07	6.90	India
Rice	8.73 [106]	-	-	22.7	Indonesia
	9.00 [107]	-	-	23.4	Taiwan
Winter oilseed rape	4.56 [88]	3.67 [88]	0.14 [88]	13.0 [88]	Poland
	5.35 [108]	3.72	0.19	15.2	Czech Republic
	5.48 [109]	3.88	0.26	15.6	Latvia
	3.90 [110]	2.70	0.18	11.2	The United Kingdom
	2.99 [111]	2.00	0.17	8.50	Serbia
Soybean	3.47 [68]	3.12 [88]	0.25 [88]	10.6 [88]	Poland
	3.40 [112]	3.07	0.27	10.4	Brazil
	3.30 [113]	2.98	0.23	10.0	Serbia
	3.24 [114]	2.87	0.20	9.8	Kazakhstan
Lentil	1.14 [88]	0.85 [88]	0.17 [88]	3.3 [88]	Poland
	2.22 [115]	1.64	0.21	6.4	Greece
	3.16 [116]	2.35	0.30	9.1	Ukraine
	1.54 [117]	1.15	0.17	4.4	India

Table 1. *Cont.*

Crops	Primary Yield: Grain/Seeds, Roots, Tubers, Biomass * (t ha^{-1})	Secondary Yield: Straw, Stems, Leaves (t ha^{-1})	Below-Ground Crop Residues/Roots (t ha^{-1})	Total Carbon Sequestration in Biomass of Primary, Secondary Yield and Roots (t CO_2 ha^{-1} yr^{-1})	Additional Data
1	2	3	4	5	6
Potato	32.30 [88]	18.90 [88]	0.19 [88]	43.2 [88]	Poland
	40.00 [118]	23.40	0.36	53.5	Ethiopia
	33.00 [119]	19.30	0.20	44.2	Rwanda
	33.93 [120]	19.90	0.21	45.4	Canada
Sugar beet	60.20 [68]	47.10 [88]	-	80.4 [88]	Poland
	53.00 [121]	41.50	-	70.8	Hungary
	84.90 [122]	66.40	-	113.0	Croatia
	81.69 [123]	64.00	-	109.0	Iran
	63.96 [124]	50.00	-	85.4	Iran
Carrot	55.40 [68]	-	-	71.8 [68]	Poland
	35.90 [125]	-	-	46.5	Bangladesh
	22.60 [126]	-	-	29.3	Ethiopia
	35.00 [127]	-	-	45.4	Brazil
	42.29 [128]	-	-	54.8	Bangladesh

* Depending on crop type. The yield of CO_2 sequestration was calculated by taking into account the annual yield of the plant (tonnes dry weight ha^{-1} yr^{-1}), carbon content in the biomass of individual crops: for cereals 42% dry weight (the value compared with data given by Ma et al. [129]) and for rapeseed 43%, and a carbon to CO_2 conversion factor of 3.67. If the reference number was not given alongside, the values in columns 3–5 were calculated assuming the same share between primary, secondary and below-ground biomass weight as in Ref. [88].

From the data in Table 1, it can be seen that the highest primary and secondary yields (much higher compared to other crops) are characterized by root crops (beet, carrot) [88,122,123,127,128] and tuber crops (potato) [118–120]. Under China's soil and climate conditions in the Xinjiang Region, maize cultivated in the research station was characterized by very high primary and secondary productivity [102]. This means that the species producing the highest biomass in primary and secondary yields have the highest CO_2 sequestration. Nevertheless, not all of the listed species (i.e., beet and carrot) are leading crops in the crop structure globally. Instead, crops are dominated by cereal crops (e.g., maize, rice and wheat) and the potato, which form the food base for about 5 billion people [90,130–132]. Therefore, it is the cereal crop group that potentially has the greatest impact on carbon sequestration [133]. The management and sustainable use of resources, e.g., water, land and nutrients, will be crucial to improving food security. Achieving a balance between environment protection and food and nutritional security and addressing climate change constitute key issues for sustainable food systems, as well as for the management and use of water and land [134,135].

Considering the data in Table 1, it can be noted that the listed leading cereal species exhibit high yields [89,92,98]. Winter rapeseed [108] and soybean [112] are also characterized by high yields. The aforementioned crop species show significantly higher primary and secondary yields and significantly higher CO_2 sequestration compared to the low-yielding species: buckwheat, millet and lentil. Species such as maize and soybean have the highest crop residues, while other cereals, especially millet, have significantly lower crop residues. When relating the productivity of the plant species included in Table 1 to the scale of CO_2 sequestration by them, it should be noted that the species showing the highest sequestration

include beet (70–113 t CO_2 ha^{-1} yr^{-1}), potato (43–53 t CO_2 ha^{-1} yr^{-1}), carrot (29–71 t CO_2 ha^{-1} yr^{-1}), and maize (14–45 t CO_2 ha^{-1} yr^{-1}).

In order to satisfy the demand for food of the constantly growing population which is expected to grow further, exceeding 9 billion people by the year 2050, it is necessary to increase the production of cereal by roughly 70%. Potential strategies for coping with the effects of climate change and increasing crop yields are becoming very important. These involve integrating modern and conventional molecular techniques and use of genomic approaches, as well as implementing best practices related to agricultural management and the cultivation of climate-resilient cereals. Among cereal crops, millet deserves special attention, because its cultivation is less resource-intensive and releases fewer greenhouse gases in comparison with other cereal crops. Hence, millets may constitute prospective crops for climate-resilient studies, the results of which allow for improving the properties of the major cereals [136]. Millet constitutes a C4 crop capable of fixing carbon at decreased transpiration rate, in comparison with other cereals (C3 crop), e.g., wheat and rice [137,138]. In the case of C4 crops, photorespiration under elevated CO_2 as well as temperature in the atmosphere is significantly reduced [139]. In addition, the prevailing model of climate projection shows that the yield of C4 crops is likely to grow by as much as 38%, in comparison to the relatively constant yields of C3 crops [140]. Other advantages related to C4 photosynthesis involve enhanced ecological enactment and growth at high temperatures, more flexible patterns of biomass allocation and decreased hydraulic conductivity per unit leaf area [141].

The main carbon exchange occurs between the terrestrial ecosystem and the atmosphere, which corresponds to the CO_2 incorporation into plant biomass through photosynthesis, amounting to 123 GT yr^{-1}. Approximately 60 GT of CO_2 captured by plants is returned to the atmosphere due to plant respiration [142]. The remaining amount, being the net primary productivity (NPP), is built-up into the biomass, but partially released due to the anthropogenic activities connected with biomass use and through microbial respiration. Only ca. 10 GT yr^{-1} is defined as the net ecosystem productivity (NEP), but when considering carbon retention on a long-term scale, further carbon loss is observed due to changes in land use, fires, etc. Finally, the C (bio)sequestration in a terrestrial ecosystem considered as the net biome productivity (NBP) is significantly lower. During recent decades it was estimated to be in range from 0.3 to 5.0 GT yr^{-1} [142,143]. A current estimation from 2018 showed that terrestrial ecosystems constitute a carbon sink with a net value reaching 3 GT yr^{-1} [34]. However, a significant part of the CO_2 captured in photosynthesis is quickly returned to the atmosphere, whereas the stable soil-carbon pool is increased only to a limited extent. Therefore, the selection of appropriate plant species (high CO_2 sequestration rate), and especially the changing the soil-carbon budget, even by a few percent, represent a great potential for mitigating climate change [62]. An important issue in plant selection is also their ability to resist climate change. The main morphological characteristics of crop plants that determine their resistance to these changes are low leaf area, low growth and thick cell walls, as well as an extensive root system [144]. Another important factor influencing carbon sequestration in terrestrial ecosystems is the depth of the root system. The deep location of the roots related to deep organic matter deposition in soil favor the extension of carbon residence time, because the rate of biomass decomposition in weakly aerated deeper soil profiles is lower compared to that occurring in surface horizons. In addition, deeper roots may—to a certain extent—mitigate the impact of droughts, hence additionally enhancing the uptake of carbon. Widespread application of plant selection to enhance the sequestration of carbon is simple method with significant economic potential, which is yet untapped [145,146].

Under the conditions of increased CO_2 levels in the atmosphere, the C3 crops might be faced with nitrogen limitation; thus, the higher root biomass becomes an even greater advantage [147]. According to estimates, adopting the phenotypes of annual crops which are characterized by larger and deeper root systems might contribute to soil carbon-stock increases amounting to 0.5 GT CO_2 ha^{-1} yr^{-1} on current cropland in the USA [148].

Some authors [149–151] argue that designing crops for low-carbon farming as well as improvements with the soil-carbon budget in mind are not likely to constitute a cost-effective method. Farmers would have to receive a financial return through tax credits as well as cap-and-trade programs. The aforementioned authors believe that, although improving the condition of soil by enhancing the soil-carbon pool will promote crop productivity, it is unlikely to sustain high yields of crops designed to direct a significant portion of photosynthesis to the soil. Consequently, measures will be needed to increase the efficiency of photosynthetic energy conversion and thus biomass production.

Yields of crop plants are limited by photosynthesis, as well as the scheme of allocation of photosynthesis products to its organs, which constitutes its sink strength. Accumulation of carbohydrates in leaves as well as feedback inhibition of photosynthesis may occur if source strength is not matched by sink strength [152,153]. Because high CO_2 concentration in the atmosphere increase source strength to a greater extent than sink strength, focusing on improving sink strength alongside photosynthesis will be of even greater importance [154]. Carbon capture and the yield of plants can be increased via optimization of the regulatory processes determining sink strength within heterotrophic organs, combined with the efforts to overcome the feedback inhibition relating to photosynthesis [155].

5. Catch and Cover Crops as an Important Carbon Sequestration Factor in Agricultural Sector

One of the barriers to the development of a low-carbon economy in many rural areas is the inadequate selection of crops in rotation, as well as the insufficient use of catch and cover crops (C&C crops), which leave a large amount of biomass in the form of crop residues. An important opportunity for the development of carbon farming may be the projected increase in the importance of these catch crops, cover crops and nitrogen-fixing crops as a result of the new system of direct payments from European Union funds and the promotion of a sustainable farming system and the prevention of SOM loss.

The crops with high potential for SOM formation include, among others, legumes: faba bean (*Vicia faba*), narrowleaf lupin (*Lupinus angustifolius*), yellow lupin (*Lupinus luteus* L.), pea (*Pisum sativum* L.); small-seeded legumes: red clover (*Trifolium pratense* L.), alfalfa (*Medicago sativa* L.), vetches (*Vicia sativa* ssp.), serradella (*Ornithopus* L.); grasses: perennial ryegrass (*Lolium perenne* L.), orchard grass (*Dactylis glomerata* L.) and mixtures of the mentioned plants, as well as *Brassicaceae*: white mustard (*Sinapis alba*); *Boraginaceae*: blue phacelia (*Phacelia tanacetifolia*).

Ecological Focus Areas (EFAs) are one of the three new greening measures of the CAP. These areas should be beneficial for the climate and the environment. According to the CAP, farmers having more than 15 ha of arable land must ensure that at least 5% of this land belongs to an EFA. Areas subjected to catch or cover crop cultivation are included in an EFA [156,157]. Therefore, in plant production, efforts should be focused on using the crops with a high capacity for the production of SOM, which can be obtained by plowing in biomass, as well as by using post-harvest residues remaining on the field [158–160].

Studies on nutrient cycling in the agroecosystem and nutrient losses, some initiated as early as the 1990s [161,162] and continuing today [163–165], have shown the need to increase the area of catch and cover crop cultivation, which is becoming an essential component in the system of integrated and ecological agriculture. Catch crops are plants cultivated in pure sowing or in mixtures, in rotation between two main crops [166,167]. Its general role is the prevention of nitrogen leaching, while the main role of cover crops is to protect soils from erosion, the decrease of organic matter and weed suppression. Leguminous crops are mainly used as green manure, in order to improve the N supply for succeeding crops [168]. Catch crops are mainly plants with a short growing seasons, used during the vegetative or in the initial period of generative plant growth. Their biomass can be also used as fodder or as a source of SOM and nutrients [169,170].

In the past, catch crops were viewed mainly as a source of additional fodder for animals, and their species were selected for their forage values. Nowadays, catch crops

are considered in multiple terms, with their main importance being their phytosanitary, fertilizer, structure-building and conservation values [33,164], as well as, more recently, their contribution to mitigating the negative effects of climate warming [88,171,172]. Cerda et al. [173] showed that the farming community in Spain considers catch crops more in terms of their benefit to the environment and society than their yield-forming benefit.

Depending on the sowing date, three types of C&C crops are distinguished in Europe:

1. Stubble crops—seeds are sown in summer, and the plants are harvested in autumn for green fodder and mowed and plowed, or plowed without mowing. Plants can also be left as mulch after mowing for the winter. The most commonly grown species in stubble crops include white mustard, black mustard, rapeseed, oil radish, faba bean, yellow lupine, narrow-leaved lupine, field pea, spring vetch, serradella, blue phacelia, sunflower and oats [166,174]. When selecting mixtures, no more than 2–4 plant species should be included in their composition. The mix should include species with a similar length of growing season and similar uses [175,176].
2. Undersown crops—sown in spring into spring cereals or sown together with them, and (less often) sown into winter cereals. They are used similarly to stubble crops in autumn (i.e., forage, biomass for plowing and mulch). The most commonly grown undersown crops include red clover, white clover, alfalfa and serradella, with grasses such as Westerwold ryegrass, cocksfoot grass, perennial ryegrass, Italian ryegrass and bromegrass, and mixtures of the mentioned plants.
3. Winter cover crops—sown in late summer or autumn and harvested the following spring. Winter cover crops include, inter alia, Brassica rapa, winter rape, winter rye in pure and mixed stands with hairy vetch, a mixed stand of winter rye with hairy vetch and Italian clover (crimson clover), and a pure stand of Westerwold ryegrass or Italian clover, as well as mixed stands or perennial ryegrass with winter vetch and Italian clover [177,178].

Due to their beneficial environmental impact, catch and cover crops have now become an instrumental for creating environmentally friendly agriculture [167,169].

Under the conditions of good soil and moist habitats, growing a white mustard catch crop increases spring cereal yields by 8–10%. The productivity of catch crops depends largely on weather factors, so it is expedient to determine which species are best-suited to a particular region of the country [160,179,180]. The disadvantage of catch crops is the unreliability of yields, resulting especially from their vulnerability in the first weeks after sowing the seeds [164].

Kwiatkowski et al. [160] and Harasim et al. [164] note that the introduction of conservation tillage (without the use of a plow) did not translate into a difference related to the productivity of stubble crops compared to plow tillage. The yield of air-dry matter of stubble crops on the sites with conservation tillage was, on average, lower only by 0.1–0.2 t (about 3.5%) than that obtained with the technology using a share plow. Considering the final yield (after mowing) of catch crop biomass, the authors found that white mustard had the highest productivity, regardless of tillage method. An equally high yield of air-dried biomass (yield of air-dried biomass, lower by only 2.7% than white mustard) was obtained from cultivation of the blue phacelia stubble crop. A legume mixture proved to be an unreliable catch crop, yielding about 60% less than the other species. This was mainly due to the very small share of the faba bean component in the total yield, which accounted for only about 28% of the yield of the whole mixture.

The yield of intercrops varies significantly (Table 2) and is highly dependent on soil quality and initial nutrient abundance [160,180]. The subsequent beneficial impact of crop residues depends mainly on the rate of decomposition and the amount of nutrients released from them, and this is directly related to biomass quality, i.e., C/N ratio and lignin content [174].

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Table 2. Average yield of catch crop (dry matter) and average carbon dioxide sequestration in biomass.

Crops	Biomass Yield ($t \cdot ha^{-1}$)		Carbon Dioxide Sequestration ($t\ CO_2\ ha^{-1} \cdot yr^{-1}$) *		References **
	Above Ground Biomass	Below-Ground Biomass	Above Ground Biomass	Below-Ground Biomass	
1	2	3	4	5	6
White mustard	3.49	0.33	5.38	0.51	Gentsch et al. [170]
	4.26	0.13	6.57	0.20	Kwiatkowski et al. [88]
	9.60	0.14	14.80	0.22	Selzer and Schubert [183]
	4.16	0.76	6.41	1.17	Gentsch et al. [184]
	3.70	0.26	5.70	0.40	Gazoulis et al. [185]
	4.50	0.15	6.94	0.23	Heuermann et al. [186]
Tansy phacelia	3.98	0.08	6.13	0.12	Kwiatkowski et al. [88]
	7.00	0.14	10.79	0.22	Selzer and Schubert [183]
	4.15	0.12	6.40	0.18	Heuermann et al. [186]
	5.34	0.65	8.23	1.00	Gentsch et al. [184]
Red clover	1.70	0.08	2.62	0.12	Liu et al. [187]
	2.69	0.06	4.15	0.09	Kwiatkowski et al. [88]
	1.94	0.45	2.99	0.69	Gentsch et al. [184]
Egyptian clover	3.50	0.21	5.39	0.32	Heuermann et al. [186]
Serradella	3.05	0.07	4.70	0.11	Kwiatkowski et al. [88]
Westerwolds ryegrass	2.42	0.05	3.73	0.08	Kwiatkowski et al. [88]
Perennial ryegrass	2.00	0.05	3.08	0.08	Selzer and Schubert [183]
	1.80	0.06	2.77	0.09	Liu et al. [187]
Perennial ryegrass + winter vetch	3.11	0.12	4.79	0.18	Kwiatkowski et al. [88]
Faba bean	1.75	0.25	2.70	0.39	Talgre et al. [188]
White lupine	2.10	0.11	3.24	0.17	Selzer and Schubert [183]
Spring vetch + field pea	3.46	0.21	5.33	0.32	Pawłowski et al. [172]
Yellow lupine	2.72	0.30	4.19	0.46	Kwiatkowski et al. [88]
Oats	4.95	0.26	7.63	0.40	Gentsch et al. [184]
Oats + spring vetch + field pea	3.22	0.16	4.96	0.25	Pawłowski et al. [172]
Winter rye	4.07	0.13	6.27	0.20	Kwiatkowski et al. [88]
Winter vetch	2.97	0.12	4.58	0.18	Pawłowski et al. [172]

* The yield of CO_2 sequestration was calculated taking into account the annual yield of the plant (tonnes dry weight $ha^{-1}\ yr^{-1}$), with the carbon content in biomass assumed as 42% dry weight, and carbon to CO_2 conversion factor equal to 3.67. ** sources of data given in columns 2 and 3.

According to a study by Kwiatkowski et al. [88], catch crops represent a significant added value (+25–30%) of carbon sequestration in relation to the cultivation of the main crops in the crop structure in Poland. In fact, catch crops are primarily grown in-between cereals in the main crop. Thus, they are an important factor in CO_2 sequestration in agriculture.

Pawlowski et al. [189] showed that, in Poland, the area of intercrops amounts to 1177 mln ha. According to calculations, the amount of carbon dioxide absorbed by these catch crops amounts to 6.85 mln tonnes of CO_2 yr^{-1}. If it is assumed that the interest of farmers in the cultivation of catch crops will continue, the authors conclude that the area of sown catch crops will be increased by approximately one-third within the next decade. This will expand the current area to roughly 1530 mln ha, whereas the yearly CO_2 sequestration will be increased to 8.88 mln tonnes of CO_2 yr^{-1}. This forecast is feasible, especially when such activities are promoted to a greater extent. To compare, in 2018, the total yearly CO_2 emissions in Poland amounted to 305.75 mln tonnes of CO_2 [190], and the total greenhouse gas emissions from agriculture, expressed as CO_2 equivalent, reached 30.05 mln tonnes [131,191]. Therefore, catch crops are capable of mitigating about 6% of Poland's annual CO_2 emissions and can offset over 50% of agricultural GHG emissions in the country. Moreover, the carbon absorption in catch crops is equivalent to one-fifth of the carbon in the cereal biomass (e.g., triticale, oats, barley, rye and wheat) that constitute the dominant crops cultivated in Poland [172]. Previous studies [172,189] have shown that the cereals grown in Poland absorb 23.8 million tons of carbon per year, equivalent to 87.3 million tonnes of CO_2.

The potential increase in the area available for catch crops cultivation in Poland is higher than in France, Spain or Romania, but lower than in Denmark. For example, the value of this parameter, estimated on the basis of the total area under cereal, protein and industrial crops in the Overijssel region of Denmark is 90%, but in some regions of Spain, Romania and France it is below 20% [192]. Such variation results from highly prevalent cultivation of catch crops in the considered regions. For instance, catch crops cultivation enjoys great popularity in France [192]; therefore, the potential for expanding the area of catch crops cultivation is lower than in the countries in which such practices are employed less frequently. The projected scale of CO_2 sequestration as a result of catch crops cultivation can be even greater when focusing on growing the species characterized by highest productivity, namely tansy phacelia, white mustard, oats, winter rye, and a mixture of spring vetch and pea (which attain the highest CO_2 sequestration parameters) [172,193].

It should be emphasized that, in addition to yield-forming functions and climate protection, cultivation of catch crops can also have economic effects. Farmers choosing to grow catch crops can benefit from direct subsidies from EU funds for growing these crops. In addition, the use of catch or cover crops improves soil quality, which is associated with increased yields of the main crops and leads to increased economic efficiency on the farm.

Pawlowski et al. [171] found that the use of catch crops significantly increased the yield and economic value of spring wheat grain. In addition, the economic profitability of monoculture spring wheat cultivation with catch crops increased due to direct subsidies for catch crops from EU funds under the RDP. Consequently, the highest gross margin (657.1 € ha^{-1}) was obtained by cultivation with the white mustard catch crop, followed by the blue phacelia catch crop (622.7 € ha^{-1}).

According to a study by Pawlowska et al. [35], another possibility for additional use of catch crop biomass, increasing the profitability of its use, is the production of green energy. Underground biomass and some of the above-ground catch crop biomass is deposited in the soil as a source of carbon sequestration, while some of the above-ground biomass may be employed for biogas or syngas production. The use of biomass for energy production is environmentally beneficial, as it provides fuel with low environmental impact, and the residue from the process in the form of digestate or biochar can be returned to the soil to act as a fertilizer or soil quality improver. The yield of biomethane production from catch crops grown in Poland ranges from 965 m^3 ha^{-1} (narrow-leafed lupine) to 1762 m^3 ha^{-1} (winter rye and spring vetch with field pea). The potential for biomethane production from individual catch crops grown in Poland, taking into account the area of their sowing, ranges from 61 (narrow-leafed lupine) to 328 million m^3 yr^{-1} (white mustard) [172].

6. Carbon Sequestration in Soil as a Climate Change Mitigation Strategy

Soil's organic carbon plays an important role in achieving sustainable agroecosystems by increasing crop productivity and sequestering atmospheric carbon. SOC promotes crop productivity by improving nutrient retention and water holding capacity, facilitating efficient drainage and aeration, minimizing topsoil loss through erosion and providing substrates for soil microbiomes [44,194]. SOC can be sequestered in permanent pools, such as by conversion to biochar or through organo-mineral and organometallic interactions [143,195]. The a ddition of biochar changes the physicochemical parameters of the soil. Significantly, though, the direction and range of these changes depend on the properties of the biochar, which are related to the chemical composition of substrate used in biochar production and technological conditions of thermochemical conversion [196]. Biochar differs in terms of pH. The value of this parameter depends on the rate of the carbonization process, the pyrolysis temperature and the type of raw material [197]. Biochar contains organic acids which are generated during biomass pyrolysis, and thus it can influence the final pH of the soil [198]. Because of its sorption properties, biochar can influence soil processes and gas emissions from the soil, e.g., NH_3 [199]. At the same time, biochar improves soil C-organic content and contributes to better use by plants of nutrients contained in the soil [Hossain et al. [200]. Carbon derived from biochar may also be converted to inorganic soil compounds, e.g., magnesium and calcium carbonates, which are stored in the soil long-term [201].

In order to rationally design, develop and implement the crops adapted to carbon agriculture, in the long term it will be necessary to improve modeling of the metabolic nitrogen and carbon fluxes and, subsequently, to understand the control mechanisms thereof. The next step will be to implement this knowledge in order to model the interactions between carbon sequestration pathways and source-sinks in integrated plant–microbe–soil systems via genome editing and engineering. The theses above are supported by some scientific reports from which guidelines can be drawn for the development of metabolic flow models [202–204] and genome-scale metabolic networks [205].

Jansson et al. [140] noted that pastures and agricultural cropping systems constituted one-third of global arable land, having the potential for drawing down significant amounts of carbon dioxide in the atmosphere to be stored as SOC as well as enhancing the soil-carbon budget. The purpose of an enhanced soil-carbon budget is twofold: it promotes soil health, supporting crop productivity, as well as constituting a pool for conversion of carbon to its recalcitrant forms, facilitating the long-term storage which is employed to mitigate global warming.

The content of soil-carbon is regulated by a balance between the inputs resulting from photosynthesis, plant root exudates, and additives such as compost and manure, as well as the outputs via root and microbial respiration and soil emissions. In the process of carbon allocation, the assimilated atmospheric carbon dioxide is subject to shifts between respiration, biomass production and enduring and transient tissues, as well as below-ground and above-ground components. According to functional or optimal equilibrium theories, resources are allocated by plants among their organs in order to ensure optimal fitness [206,207].

The distribution of the products of photosynthesis between above- and below-ground biomass in a plant changes depending on environmental variables, e.g., availability of nutrients and light, as well as soil moisture. Significant amounts (20–30%) of recent photosynthates are allocated by plants to the below-ground biomass. Approximately half of this carbon is utilized for the growth of roots, whereas its largest fraction (up to 30%) is then released to the rhizosphere, either via mycorrhiza or sloughed root cap cells, or through exudation; some part is lost in the course of respiration. Under limited light conditions, plants accumulate more carbon in their shoots, while under water- and nutrient-limited conditions, they divert more carbon to their roots [208,209].

Poeplau and Don [158] quantified the overall potential of catch crop cultivation intended to increase SOC based on data from 139 plots at 37 different sites. In their view,

cover crops used as green manure are an important management option for increasing SOC stocks in agricultural soils. The authors considered most of the available studies on cover crops worldwide and found that the average annual sequestration of SOC ranged widely, from 0.32 ± 0.08 Mg $ha^{-1} \cdot yr^{-1}$ to 16.7 Mg $ha^{-1} \cdot yr^{-1}$.

Chahal et al. [157] demonstrated the positive effect of catch crops (oilseed radish, oat, cereal rye, and a mixture of oilseed radish + rye) on increasing C-organic storage in surface soil after using them six times over 8 years. Of the catch crops tested, oilseed radish contributed the highest cumulative carbon sequestration by above-ground plant parts and the greatest SOC gains. Compared to the control without catch crops, all soils under catch crops had higher SOC content, and main crop plants (cereals) grown after catch crops' cultivation had better yields, indicating the usefulness of the tested catch crops for improving soil functionality, primary productivity and sequestration of atmospheric CO_2 in temperate and humid climates.

In the study by Kwiatkowski et al. [160], all the catch crops included in the experiment (white mustard, tansy phacelia, and faba bean + spring vetch mixture), regardless of the tillage method, caused a statistically proven increase in SOC content compared to the control object, but had no significant effect on total nitrogen content.

An undeniably positive effect of catch crops is the prevention of nitrate leaching, the amount of which after the end of vegetation in autumn is on average 30% less than in soil without catch crops. Evaluation of the effectiveness of catch crops varies and is highly dependent on soil quality and initial nutrient abundance [160]. The beneficial subsequent effect of crop residues depends mainly on the rate of decomposition and the amount of nutrients released from them, and this is directly related to the quality of the biomass, i.e., the C/N ratio and lignin content [175,182].

Plant root systems are vital in providing and storing SOC. However, it is unclear which characteristics of roots are essential for maximization of SOC as well as for long-term storage of carbon. In order to achieve a high soil-carbon pool, high root-carbon inputs are an essential, but insufficient, precondition. For instance, higher root exudation and increased root biomass, both stimulated by greater levels of CO_2, do not always contribute to high gains of soil-carbon. This phenomenon can be explained by increased microbial activity and enhanced priming of old soil organic matter [210,211].

A field trial conducted over a period of 9 years that compared switchgrass monoculture, highly biodiverse native succession vegetation, and two perennial herbaceous systems and showed that, although the root biomass of switchgrass exceeded that of native vegetation by more than 10-fold, the levels of soil organic carbon under switchgrass exhibited markedly lower improvements [212]. This example shows that it cannot be unequivocally stated that breeding plants to achieve greater root biomass constitutes the solution for enabling quicker and more efficient storage of carbon in the soil. Instead, some authors have detailed plant characteristics that can lead to increased SOC. First, they point to the physical features characterizing the structure of a root system, rather than simply total root biomass. They also take into account root morphology, the complexity of which promotes soil structure [213–215]. The amount of carbon that enters the soil as root exudation in the course of plant growth is also important [133,216]. Further factors influencing greater soil-carbon storage include the chemical composition of root tissues and root exudation [217,218], as well as the development of a rhizosphere microbiome capable of converting the carbon contained in root biomass into SOC [219].

According to Zhang et al. [220], the no-tillage system resulted in a significant increase in the SOC of the topsoil (0–30 cm), as compared to conventional tillage. Furthermore, SOC could be increased and greenhouse gas emissions reduced by increasing the complexity of crop rotation and straw return, as noted in study [221].

Jansson et al. [147] proposed a comprehensive approach to the integrated plant–microbe–soil system and suggested the possibility of achieving marked improvements related to SOC storage via the following approach:

(1) Selecting plants characterized by high root strength in order to further sequester carbon in the soil;
(2) Balancing the increased allocation of below-ground carbon with greater source strength for improved biomass accumulation and photosynthesis;
(3) Designing consortia of soil microbes for improved strength of rhizosphere sink as well as properties promoting plant growth.

Amelung et al. [77] believe that sustainable soil-carbon sequestration practices must be rapidly expanded and implemented, and thereby contribute to climate change mitigation. The authors emphasize that the main potential for carbon sequestration is in the soils of croplands, especially those with large yield differences or large temporal losses of soil organic carbon. Implementing soil-carbon sequestration measures requires a diverse set of options, each tailored to local soil conditions and crop management. The authors suggest creating a soil information system on low-carbon farms regarding the soil group, its degradation status, yield differences, and associated carbon sequestration potential, as well as providing policies (financial incentives) to translate management options into region- and soil-specific practices.

The European Commission [222] provides guidance on low-carbon farming. According to these guidelines, low-carbon farming on mineral soils involves measures to improve the level of soil organic carbon (SOC) on croplands and grasslands. Increasing SOC levels can directly promote the restoration of biodiversity, as microorganisms responsible for biochemical processes in soil require appropriate SOC levels. Additionally, high crop biodiversity can further enhance SOC accumulation. The Biodiversity Strategy to 2030 (BDS) emphasized the close relationship between soil health and biodiversity, leading to the proposal of a new strategy to address soil degradation in Europe. The EU Nature Restoration Plan will play a significant role in this strategy by including soil restoration targets to reduce soil erosion, protect soil fertility and increase the content of SOC. Low-carbon farming can play a direct role in achieving these targets and can aid in the implementation of the national restoration plans which Member States are expected to develop by 2023. Carbon farming can also indirectly contribute to the restoration of farmland biodiversity through measures such as improved crop rotations and cover cropping as well as the restoration of permanent grassland, which can provide habitats for endangered species. Additionally, carbon farming can help alleviate the pressure on biodiversity by enhancing nutrient availability, improving soil structure, and increasing water retention. This, in turn, leads to greater productivity and a reduced need for fertilizers. Furthermore, low-carbon farming on mineral soil can fulfill the EU nature restoration law's objectives by promoting increased water retention, minimized run-off, and reduced erosion risk [223].

Low-carbon agriculture offers a long-term opportunity to tap the considerable potential related to linking agriculture to the rhizosphere microbiome regarding promotion of soil-carbon sequestration. In this regard, designing low-carbon agriculture crops is consistent with the consensus of the Paris Climate Agreement mandating the economically optimal pathways aimed at mitigating global warming, which should not only mandate the reduction of greenhouse gas emissions, but also have to include negative emissions technologies, e.g., stimulating the soil to achieve greater carbon storage [224].

According to present research, an annual growth of carbon stored in soils of 0.4% could halt the current increase of CO_2 in the atmosphere [225]. Many national strategies for meeting climate goals incorporate programs for soil-carbon sequestration. An analysis of the first round of Nationally Determined Contributions (NDCs) to the United Nations Framework Convention on Climate Change found that 28 countries mentioned the increase of soil organic carbon in their pledges, while 14 of them referred specifically to agricultural lands. However, only 15% of countries included a strategy of SOC increase in their climate pledges, suggesting that many hesitate to officially include soil-carbon sequestration into environmental policy due to the difficulties in monitoring or quantifying SOC content [226]. There are several aspects covered in the studies on the implementation of soil-carbon sequestration practices. One of them pertains to the beliefs of farmers regarding the

reliability of the science indicating climate change, and their readiness to take the necessary action to mitigate or adapt to it. The actions include the use of "climate-smart" practices, which have significant overlaps with soil-carbon sequestering practices [227]. The term "climate-smart agriculture" was coined around ten years ago, and it involves reducing greenhouse gas emissions from agriculture while simultaneously enhancing adaptive capacity [228].

7. Conclusions

Bio-sequestration in plants and sequestration in soil are the simplest methods of reducing CO_2 emissions into the atmosphere. As crops build yields, they remove CO_2 from the atmosphere, and the biomass produced becomes a temporary carbon sink. This means that increasing the overall yield of plant biomass, both the main crop and intercrops, by use of skillful agrotechnics will help to reduce the CO_2 concentrations in the atmosphere.

Low-carbon agriculture, especially crop production, can be an effective and simple way to mitigate global warming. However, proper crop management is necessary, including the selection of plant species appropriate to the given soil and climate conditions. A key factor influencing the uptake of carbon farming is the provision of adequate financial incentives that would be sufficiently equivalent to farmers to compensate for the potential reductions in crop productivity or production profitability due to the transition to low-carbon farming. Successful catch crop cultivation can increase the CO_2 sequestration from the atmosphere by as much as 20–25%, compared to the sequestration of the main crop without catch crop cultivation.

However, in an overall quantitative assessment of the contribution of carbon agriculture to carbon sequestration, long-term carbon retention is key, and it depends on many factors related to both soil properties and climatic conditions. Unfortunately, the information available in this regard is impoverished, which presents a barrier to estimates. Catch crops, the biomass of which largely remains in the soil—unlike that of the main crop—could play an important role in strategies to increase soil-carbon stocks and mitigate climate change. However, further research is needed, the results of which will identify the pathways to intensifying the formation of permanent forms of SOM and the predominance of humification processes over mineralization, as tailored to specific local conditions. They must take into account both environmental and socio-economic conditions, including the proper selection of plants, existing technical capabilities, and farmers' attitudes toward the proposed solutions, as well as the cost-effectiveness of changes in the farming system and their life-cycle analysis.

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References

1. Kargwal, R.; Yadvika; Kumar, A.; Garg, M.K.; Chanakaewsomboon, I. A review on global energy use patterns in major crop production systems. *Environ. Sci. Adv.* **2022**, *1*, 662–679. [CrossRef]
2. Woods, J.; Williams, A.; Hughes, J.K.; Black, M.; Murphy, R. Energy and the food system. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **2010**, *27*, 2991–3006. [CrossRef]

3. Eurostat. Agri-Environmental Indicator—Energy Use. 2022. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agri-environmental_indicator_-_energy_use (accessed on 15 March 2023).
4. Rokicki, T.; Perkowska, A.; Klepacki, B.; Bórawski, P.; Bełdycka-Bórawska, A.; Michalski, K. Changes in Energy Consumption in Agriculture in the EU Countries. *Energies* **2021**, *14*, 1570. [CrossRef]
5. Our World in Data 1. Sector by Sector: Where do Global Greenhouse Gas Emissions Come from? Available online: https://ourworldindata.org/ghg-emissions-by-sector (accessed on 12 March 2023).
6. Flammini, A.; Pan, X.; Tubiello, F.N.; Qiu, S.Y.; Rocha Souza, L.; Quadrelli, R.; Bracco, S.; Benoit, P.; Sims, R. Emissions of greenhouse gases from energy use in agriculture, forestry and fisheries: 1970–2019. *Earth Syst. Sci. Data* **2022**, *14*, 811–821. [CrossRef]
7. FAO. Emissions Due to Agriculture. Global, Regional and Country Trends 2000–2018. 2020. Available online: https://www.fao.org/3/cb3808en/cb3808en.pdf (accessed on 12 March 2023).
8. OECD FAO. Agricultural Outlook 2022–2031. Available online: https://www.oecd-ilibrary.org/sites/ab129327-en/index.html?itemId=/content/component/ab129327-en (accessed on 12 March 2023).
9. EPA. Understanding Global Warming Potentials. Available online: https://www.epa.gov/ghgemissions/understanding-global-warming-potentials (accessed on 13 March 2023).
10. Ocko, I.B.; Sun, T.; Shindell, D.; Oppenheimer, M.; Hristov, A.N.; Pacala, S.W.; Mauzerall, D.L.; Xu, Y.; Hamburg, S.P. Acting rapidly to deploy readily available methane mitigation measures by sector can immediately slow global warming. *Environ. Res. Lett.* **2021**, *16*, 054042. [CrossRef]
11. IEA. *Greenhouse Gas Emissions from Energy Data Explorer*; IEA: Paris, France, 2021; Available online: https://www.iea.org/data-and-statistics/data-tools/greenhouse-gas-emissions-from-energy-data-explorer (accessed on 13 March 2023).
12. Eurostat. Energy Statistics—An Overview. 2022. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_statistics_-_an_overview#Final_energy_consumption (accessed on 15 March 2023).
13. Eurostat. Agriculture and Forestry: Energy Use Rose in 2020. 2022. Available online: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220929-2 (accessed on 13 March 2023).
14. Costa, C., Jr.; Wollenberg, E.; Benitez, M.; Newman, R.; Gardner, N.; Bellone, F. Roadmap for achieving net-zero emissions in global food systems by 2050. *Sci. Rep.* **2022**, *5*, 15064. [CrossRef]
15. Chini, L.; Hurtt, G.; Sahajpal, R.; Frolking, S.; Goldewijk, K.; Sitch, S.; Ganzenmüller, R.; Ma, L.; Ott, L.; Pongratz, J.; et al. Land-use harmonization datasets for annual global carbon budgets. *Earth Syst. Sci. Data* **2021**, *13*, 4175–4189. [CrossRef]
16. Buck, H.J.; Palumbo-Compton, A. Soil carbon sequestration as a climate strategy: What do farmers think? *Biogeochemistry* **2022**, *161*, 59–70. [CrossRef]
17. Badgery, W.B.; Mwendwa, J.M.; Anwar, M.R.; Simmons, A.T.; Broadfoot, K.M.; Rohan, M.; Singh, B.P. Unexpected increases in soil carbon eventually fell in low rainfall farming systems. *J. Environ. Manag.* **2020**, *1*, 110192. [CrossRef]
18. Smith, P.; Soussana, J.F.; Angers, D.; Schipper, L.; Chenu, C.; Rasse, D.P.; Batjes, N.H.; van Egmond, F.; McNeill, S.; Kuhnert, M.; et al. How to measure, report and verify soil carbon change to realize the potential of soil carbon sequestration for atmospheric greenhouse gas removal. *Glob. Chang. Biol.* **2020**, *26*, 219–241. [CrossRef]
19. Coutu, S.; Becker-Reshef, I.; Pellissier, L. Carbon farming: Integrate biodiversity metrics. *Nature* **2022**, *609*, 467. [CrossRef]
20. Paul, C.; Bartkowski, B.; Dönmez, C.; Don, A.; Mayer, S.; Steffens, M.; Weigl, S.; Wiesmeier, M.; Wolf, A.; Helming, K. Carbon farming: Are soil carbon certificates a suitable tool for climate change mitigation? *J. Environ. Manag.* **2023**, *330*, 117142. [CrossRef]
21. Arunrat, N.; Pumijumnong, N.; Sereenonchai, S.; Chareonwong, U. Factors Controlling Soil Organic Carbon Sequestration of Highland Agricultural Areas in the Mae Chaem Basin, Northern Thailand. *Agronomy* **2020**, *10*, 305. [CrossRef]
22. Liu, X.; Wang, S.; Zhuang, Q.; Jin, X.; Bian, Z.; Zhou, M.; Meng, Z.; Han, C.; Guo, X.; Jin, W.; et al. A Review on Carbon Source and Sink in Arable Land Ecosystems. *Land* **2022**, *11*, 580. [CrossRef]
23. Anuo, C.O.; Cooper, J.A.; Koehler-Cole, K.; Ramirez, S.; Kaiser, M. Effect of cover cropping on soil organic matter characteristics: Insights from a five-year field experiment in Nebraska. *Agric. Ecosyst. Environ.* **2023**, *347*, 108393. [CrossRef]
24. FAO 2019. Global Livestock Environmental Assessment Model (GLEAM). GLEAM 2.0. 2019. Available online: http://www.fao.org/gleam/results/en/ (accessed on 12 March 2023).
25. Clark, M.; Domingo, N.; Colgan, K.; Thakrar, S.; Tilman, D.; Lynch, J.; Hill, J. Global food system emissions could preclude achieving the 1.5° and 2 °C climate change targets. *Science* **2020**, *370*, 705–708. [CrossRef]
26. Springmann, M.; Clark, M.; Mason-D'Croz, D.; Wiebe, K.; Bodirsky, B.L.; Lassaletta, L.; de Vries, W.; Vermeulen, S.J.; Herrero, M.; Carlson, K.M.; et al. Options for keeping the food system within environmental limits. *Nature* **2018**, *562*, 519–525. [CrossRef]
27. Herrero, M.; Henderson, B.; Havlík, P.; Thornton, P.K.; Conant, R.T.; Smith, P.; Wirsenius, S.; Hristov, A.N.; Gerber, P.; Gill, M.; et al. Greenhouse gas mitigation potentials in the livestock sector. *Nat. Clim. Chang.* **2016**, *6*, 452–461. [CrossRef]
28. Cusack, D.F.; Kazanski, C.E.; Hedgpeth, A.; Chow, K.; Cordeiro, A.L.; Karpman, J.; Ryals, R. Reducing climate impacts of beef production: A synthesis of life cycle assessments across management systems and global regions. *Glob. Chang. Biol.* **2021**, *27*, 1721–1736. [CrossRef]
29. Zelitch, I. Control of plant productivity by regulation of photorespiration. *Bioscience* **1992**, *42*, 510–517. [CrossRef]
30. Lara, M.V.; Andreo, C.S. Chapter 18: C4 plants adaptation to high levels of CO_2 and to drought environments. In *Abiotic Stress in Plants—Mechanisms and Adaptations*; Shanker, A., Ed.; InTech: Rijeka, Croatia, 2011; pp. 415–428.

31. Ghannoum, O.; Evans, J.R.; Von Caemmerer, S. Nitrogen and water use efficiency of C4 plants. In *C4 Photosynthesis and Related CO_2 Concentrating Mechanisms*; Raghavendra, A.S., Sage, R.S., Eds.; Springer: New York, NY, USA, 2011; pp. 129–146. [CrossRef]
32. Venkateswarlu, B.; Shanker, A.K. Climate change and agriculture: Adaptation and mitigation stategies. *Indian J. Agron.* **2009**, *54*, 226–230.
33. Kwiatkowski, C.A.; Harasim, E.; Wesołowski, M. Effects of catch crops and tillage system on weed infestation and health of spring wheat. *J. Agric. Sci. Technol.* **2016**, *18*, 999–1012. Available online: https://www.researchgate.net/publication/305375322_ (accessed on 2 March 2023).
34. Le Quéré, C.; Andrew, R.M.; Friedlingstein, P.; Sitch, S.; Pongratz, J.; Manning, A.C.; Korsbakken, J.I.; Peters, G.P.; Canadell, J.G.; Jackson, R.B.; et al. Global Carbon Budget 2017. *Earth Syst. Sci. Data* **2018**, *10*, 405–448. [CrossRef]
35. Pawłowska, M.; Pawłowski, L.; Pawłowski, A.; Kwiatkowski, C.A.; Harasim, E. Role of intercrops in the absorption of CO_2 emitted from the combustion of fossil fuels. *Environ. Protect. Eng.* **2021**, *47*, 3. [CrossRef]
36. Huxley, P.A. Climate and Agricultural Production in Uganda. *Exp. Agric.* **1965**, *1*, 81–97. [CrossRef]
37. Anderson, J.R. Impacts of Climatic Variability in Australian Agriculture: A Review. *Rev. Mark. Agric. Econ.* **1979**, *47*, 147–177.
38. Landsberg, H.E. Man-Made Climatic Changes: Man's activities have altered the climate of urbanized areas and may affect global climate in the future. *Science* **1970**, *170*, 1265–1274. [CrossRef] [PubMed]
39. Smit, B.; Cai, Y. Climate change and agriculture in China. *Glob. Environ. Chang.* **1996**, *6*, 205–214. [CrossRef]
40. Easterling, W.E. Adapting North American agriculture to climate change in review. *Agric. For. Meteorol.* **1996**, *80*, 1–53. [CrossRef]
41. Adams, R.M.; Hurd, B.H.; Lenhart, S.; Leary, N. Effects of global climate change on agriculture: An interpretative review. *Clim. Res.* **1998**, *11*, 19–30. [CrossRef]
42. Paustian, K.; Andrén, O.; Janzen, H.H.; Lal, R.; Smith, P.; Tian, G.; Tiessen, H.; Van Noordwijk, M.; Woomer, P.L. Agricultural soils as a sink to mitigate CO_2 emissions. *Soil Use Manag.* **1997**, *13*, 230–244. [CrossRef]
43. Paustian, K.; Cole, C.V.; Sauerbeck, D.; Sampson, N. CO_2 Mitigation by Agriculture: An Overview. *Clim. Chang.* **1998**, *40*, 135–162. [CrossRef]
44. Lal, R. Soil carbon sequestration to mitigate climate change. *Geoderma* **2004**, *123*, 1–22. [CrossRef]
45. Johnson, J.M.-F.; Franzluebbers, A.J.; Lachnicht Weyers, S.; Reicosky, D.C. Agricultural opportunities to mitigate greenhouse gas emissions. *Environ. Pollut.* **2007**, *150*, 107–124. [CrossRef] [PubMed]
46. Smith, P.; Martino, D.; Cai, Z.; Gwary, D.; Janzen, H.; Kumar, P.; McCarl, B.; Ogle, S.; O'Mara, F.; Rice, C.; et al. Greenhouse gas mitigation in agriculture. *Philos. Trans. R. Soc. B* **2008**, *363*, 789–813. [CrossRef]
47. Chhabra, V.; Abdul Haris, A.; Prakash, V.; Upadhyay, H. Cropping systems and their effectiveness in adaptation and mitigation of climate change. *Plant Arch.* **2018**, *18*, 1175–1183.
48. Henderson, B.; Lankoski, J.; Sykes, E.F.A.; Payen, F.; MacLeod, M. *Soil Carbon Sequestration by Agriculture: Policy Options*; OECD Food, Agriculture and Fisheries Papers; OECD Publishing: Paris, France, 2022; p. 174. [CrossRef]
49. Murty, D.; Kirschbaum, M.U.F.; Mcmurtrie, R.E.; Mcgilvray, H. Does conversion of forest to agricultural land change soil carbon and nitrogen? A review of the literature. *Glob. Chang. Biol.* **2002**, *8*, 105–123. [CrossRef]
50. Mbow, C.; Smith, P.; Skole, D.; Duguma, L.; Mercedes Bustamant, M. Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. *Curr. Opin. Environ. Sustain.* **2014**, *6*, 8–14. [CrossRef]
51. Dalal, R.C.; Wang, W.; Robertson, G.P.; Parton, W.J. Nitrous oxide emission from Australian agricultural lands and mitigation options: A review. *Aust. J. Soil Res.* **2003**, *41*, 165–195. [CrossRef]
52. Snyder, C.S.; Bruulsema, T.W.; Jensen, T.L.; Fixen, P.E. Review of greenhouse gas emissions from crop production systems and fertilizer management effects. *Agric. Ecosyst. Environ.* **2009**, *133*, 247–266. [CrossRef]
53. Hassan, M.U.; Aamer, M.; Mahmood, A.; Awan, M.I.; Barbanti, L.; Seleiman, M.F.; Bakhsh, G.; Alkharabsheh, H.M.; Babur, E.; Shao, J.; et al. Management Strategies to Mitigate N_2O Emissions in Agriculture. *Life* **2022**, *12*, 439. [CrossRef] [PubMed]
54. Chataut, G.; Bhatta, B.; Joshi, D.; Subedi, K.; Kafle, K. Greenhouse gases emission from agricultural soil: A review. *J. Agric. Food Res.* **2023**, *11*, 100533. [CrossRef]
55. Boadi, D.; Benchaar, C.; Chiquette, J.; Massé, D. Mitigation strategies to reduce enteric methane emissions from dairy cows: Update review. *Can. J. Anim. Sci.* **2011**, *84*, 319–335. [CrossRef]
56. Davamani, V.; Parameswari, E.; Arulmani, S. Mitigation of methane gas emissions in flooded paddy soil through the utilization of methanotrophs. *Sci. Total Environ.* **2020**, *726*, 138570. [CrossRef] [PubMed]
57. Tseten, T.; Sanjorjo, R.A.; Kwon, M.; Kim, S.-W. Strategies to Mitigate Enteric Methane Emissions from Ruminant Animals. *J. Microbiol. Biotechnol.* **2022**, *28*, 269–277. [CrossRef] [PubMed]
58. Hussain, M.; Farooq, M.; Nawaz, A.; Al-Sadi, A.; Solaiman, Z.M.; Alghamdi, S.S.; Ammara, U.; Ok, Y.S.; Siddique, K. Biochar for crop production: Potential benefits and risks. *J. Soils Sediments* **2017**, *17*, 685–716. [CrossRef]
59. Qambrani, N.A.; Rahman, M.M.; Won, S.; Shim, S.; Ra, C. Biochar properties and eco-friendly applications for climate change mitigation, waste management, and wastewater treatment: A review. *Renew. Sustain. Energy Rev.* **2017**, *79*, 255–273. [CrossRef]
60. Shakoor, A.; Arif, M.S.; Shahzad, S.M.; Farooq, T.H.; Ashraf, F.; Altaf, M.; Ahmed, W.; Tufail, M.A.; Ashraf, M. Does biochar accelerate the mitigation of greenhouse gaseous emissions from agricultural soil? A global meta-analysis. *Environ. Res.* **2021**, *202*, 111789. [CrossRef]

61. Abdalla, M.; Hastings, A.; Cheng, K.; Yue, Q.; Chadwick, D.; Espenberg, M.; Truu, J.; Rees, R.M.; Smith, P. A critical review of the impacts of cover crops on nitrogen leaching, net greenhouse gas balance and crop productivity. *Glob. Chang. Biol.* **2019**, *25*, 2530–2543. [CrossRef]
62. Paustian, K.; Campbell, N.; Dorich, C.; Marx, E.; Swan, A. Assessment of Potential Greenhouse Gas Mitigation from Changes to Crop Root Mass and Architecture. Final Report for ARPA-E. Independent Consultant Agreement #107142CL/CB0471. Booz Allen Hamilton Inc. 2016. Available online: https://arpae.energy.gov/sites/default/files/documents/files/Revised_Final_Report_to_ARPA_Bounding_Analysis.pdf (accessed on 28 December 2022).
63. Creutzig, F.; Ravindranath, N.H.; Berndes, G.; Bolwig, S.; Bright, R.; Cherubini, F.; Chum, H.; Corbera, E.; Delucchi, M.; Faaij, A.; et al. Bioenergy and climate change mitigation: An assessment. *GCB Bioenergy* **2015**, *7*, 916–944. [CrossRef]
64. Sharma, M.; Kaushal, R.; Kaushik, P.; Ramakrishna, S. Carbon Farming: Prospects and Challenges. *Sustainability* **2021**, *13*, 11122. [CrossRef]
65. COWI. Ecologic Institute and IEEP: Technical Guidance Handbook—Setting up and Implementing Result-Based Carbon Farming Mechanisms in the EU Report to the European Commission, DG Climate Action, under Contract No. CLIMA/C.3/ETU/2018/007. COWI, Kongens Lyngby. 2021. Available online: https://op.europa.eu/en/publication-detail/-/publication/10acfd66-a740-11eb-9585-01aa75ed71a1/language-en (accessed on 12 March 2023).
66. EEA 2021: Greenhouse Gas Emissions from Agriculture in Europe. Available online: https://www.eea.europa.eu/ims/greenhouse-gas-emissions-from-agriculture (accessed on 12 March 2023).
67. Drexler, S.; Gensior, A.; Don, A. Carbon sequestration in hedgerow biomass and soil in the temperate climate zone. *Reg. Environ. Chang.* **2021**, *21*, 74. [CrossRef]
68. Yang, Y.; Tilman, D.; Furey, G.N.; Lehman, C. Soil carbon sequestration accelerated by restoration of grassland biodiversity. *Nat. Commun.* **2019**, *10*, 718. [CrossRef] [PubMed]
69. Roe, S.; Streck, C.; Beach, R.; Busch, J.; Chapman, M.; Daioglou, V.; Deppermann, A.; Doelman, J.; Emmet-Booth, J.; Engelmann, J.; et al. Land-based measures to mitigate climate change: Potential and feasibility by country. *Glob. Chang. Biol.* **2021**, *27*, 6025–6058. [CrossRef] [PubMed]
70. Lenaerts, B.; Collard, B.C.Y.; Demont, M. Review: Improving global food security through accelerated plant breeding. *Plant Sci.* **2019**, *287*, 110207. [CrossRef]
71. Voss-Fels, K.P.; Stahl, A.; Hickey, L.T. Q&A: Modern crop breeding for future food security. *BMC Biol.* **2019**, *17*, 638. [CrossRef]
72. Tang, K.; He, C.; Ma, C.; Wang, D. Does carbon farming provide a cost-effective option to mitigate GHG emissions? Evidence from China. *Aust. J. Agric. Resour. Econ.* **2019**, *63*, 575–592. [CrossRef]
73. Foteinis, S.; Hatzisymeon, M.; Borthwick, A.G.L.; Chatzisymeon, E. Environmental Impacts of Conventional versus Organic Eggplant Cultivation Systems: Influence of Electricity Mix, Yield, Over-Fertilization, and Transportation. *Environments* **2021**, *8*, 23. [CrossRef]
74. Aguilera, E.; Guzmán, G.; Alonso, A. Greenhouse gas emissions from conventional and organic cropping systems in Spain: II. Fruit tree orchards. *Agron. Sustain. Dev.* **2015**, *35*, 725–737. [CrossRef]
75. Tang, K.; Kragt, M.E.; Hailu, A.; Ma, C. Carbon farming economics: What have we learned? *J. Environ. Manag.* **2016**, *172*, 49–57. [CrossRef]
76. Demenois, J.; Torquebiau, E.; Arnoult, M.H.; Eglin, T.; Masse, D.; Assouma, M.H.; Blanfort, V.; Chenu, C.; Chapuis-Lardy, L.; Medoc, J.-M.; et al. Barriers and Strategies to Boost Soil Carbon Sequestration in Agriculture. *Front. Sustain. Food Syst.* **2020**, *4*, 37. [CrossRef]
77. Amelung, W.; Bossio, D.; de Vries, W.; Kögel-Knabner, I.; Lehmann, J.; Amundson, R.; Bol, R.; Collins, C.; Lal, R.; Leifeld, J.; et al. Towards a global-scale soil climate mitigation strategy. *Nat. Commun.* **2020**, *11*, 5427. [CrossRef] [PubMed]
78. White, R.E. The Role of Soil Carbon Sequestration as a Climate Change Mitigation Strategy: An Australian Case Study. *Soil Syst.* **2022**, *6*, 46. [CrossRef]
79. Shields, S.; Orme-Evans, G. The Impacts of Climate Change Mitigation Strategies on Animal Welfare. *Animals* **2015**, *21*, 361–394. [CrossRef]
80. European Court of Auditors 2021: Common Agricultural Policy and Climate: Half of EU Climate Spending but Farm Emissions Are Not Decreasing. Special Report 16/2021. Available online: https://www.eca.europa.eu/Lists/ECADocuments/SR21_16/SR_CAP-andClimate_EN.pdf (accessed on 2 March 2023).
81. COWI. *Ecologic Institute and IEEP: Annexes to Technical Guidance Handbook—Setting Up and Implementing Result-Based Carbon Farming Mechanisms in the EU. Annex—Case-Studies*; Report to the European Commission, DG Climate Action on Contract No. CLIMA/C.3/ETU/2018/007; COWI: Kongens Lyngby, Denmark, 2021. Available online: https://op.europa.eu/en/publication-detail/-/publication/99138c98-a741-11eb-9585-01aa75ed71a1/language-en (accessed on 2 March 2023).
82. Tiefenbacher, A.; Sandén, T.; Haslmayr, H.-P.; Miloczki, J.; Wenzel, W.; Spiegel, H. Optimizing Carbon Sequestration in Croplands: A Synthesis. *Agronomy* **2021**, *11*, 882. [CrossRef]
83. Ewing, P.M.; Tu, X.; Runck, B.C.; Nord, A.; Chikowo, R.; Snapp, S.S. Smallholder farms have and can store more carbon than previously estimated. *Glob. Chang. Biol.* **2023**, *29*, 1471–1483. [CrossRef] [PubMed]
84. Boody, G.; Vondracek, B.; Andow, D.A.; Krinke, M.; Westra, J.; Zimmerman, J.; Welle, P. Multifunctional agriculture in the United States. *BioScience* **2005**, *55*, 27–38. [CrossRef]

85. Jordan, N.; Boody, G.; Broussard, W.; Glover, J.D.; Keeney, D.; McCown, B.H.; McIsaac, G.; Muller, M.; Murray, H.; Neal, J.; et al. Sustainable development of the agricultural bio-economy. *Science* **2007**, *316*, 1570–1571. [CrossRef]
86. Lin, B.B.; Macfadyen, S.; Renwick, A.R.; Cunningham, S.A.; Schellhorn, N.A. Maximizing the Environmental Benefits of Carbon Farming through Ecosystem Service Delivery. *BioScience* **2013**, *63*, 793–803. [CrossRef]
87. Toensmeier, E.; Ferguson, R.; Mehra, M. Perennial vegetables: A neglected resource for biodiversity, carbon sequestration, and nutrition. *PLoS ONE* **2020**, *15*, e0234611. [CrossRef]
88. Kwiatkowski, C.A.; Harasim, E.; Pawłowski, L. Can catch crops be an important factor in carbon dioxide sequestration? *Int. J. Conserv. Sci.* **2020**, *11*, 1005–1018. Available online: http://ijcs.ro/public/IJCS-20-74_Kwiatkowski.pdf (accessed on 20 December 2022).
89. Dixon, J.; Hellin, J.; Erenstein, O.; Kosina, P. U-impact pathway for diagnosis and impact assessment of crop improvement. *J. Agric. Sci.* **2007**, *145*, 195–206. [CrossRef]
90. Grote, U.; Fasse, A.; Nguyen, T.T.; Erenstein, O. Food Security and the Dynamics of Wheat and Maize Value Chains in Africa and Asia. *Front. Sustain. Food Syst.* **2021**, *4*, 617009. [CrossRef]
91. Amirov, M.; Toloknov, D.; Safiullin, A.; Semenov, P. Influence of the nutritional level and pre-sowing seed treatment on the yield of spring wheat. *BIO Web Conf.* **2021**, *37*, 00010. [CrossRef]
92. Chen, Y.; Zhao, N.; Hao, Y.; Li, X.; Fan, M.; Shi, X.; Jia, L. Optimizing nutrient inputs by balancing spring wheat yield and environmental effects in the Hetao Irrigation District of China. *Sci. Rep.* **2022**, *12*, 22524. [CrossRef]
93. Askegaard, M.; Thomsen, I.K.; Berntsen, J.; Hovmøller, M.S.; Kristensen, K. Performance of spring barley varieties and variety mixtures as affected by manure application and their order in an organic crop rotation. *Acta Agric. Scand. B Soil Plant Sci.* **2011**, *61*, 421–430. [CrossRef]
94. Hu, Y.; Barmeier, G.; Schmidhalter, U. Genetic Variation in Grain Yield and Quality Traits of Spring Malting Barley. *Agronomy* **2021**, *11*, 1177. [CrossRef]
95. Váňová, M.; Palík, S.; Hajšlová, J.; Burešová, I. Grain quality and yield of spring barley in field trials under variable growing conditions. *Plant Soil Environ.* **2006**, *52*, 211–219. [CrossRef]
96. Kuzminykh, A.; Novoselov, S.; Eremeev, R. Winter rye yield depending on the types of fallows. *BIO Web Conf.* **2021**, *37*, 00100. [CrossRef]
97. Umarov, R.A.; Azizov, B.M. Formation of the leaf surface and grain yield of winter rye (*Secale*, L.) with the use of mineral fertilizers in irrigated soils of Uzbekistan. *Sustain. Manag. Earth Resour. Biodivers.* **2022**, *1068*, 012032. [CrossRef]
98. Duda, M.; Tritean, N.; Racz, I.; Kadar, R.; Russu, F.; Fițiu, A.; Muntean, E.; Vâtcă, A. Yield Performance of Spring Oats Varieties as a Response to Fertilization and Sowing Distance. *Agronomy* **2021**, *11*, 815. [CrossRef]
99. Mut, Z.; Akay, H.; Doğanay, Ö.; Köse, E. Grain yield, quality traits and grain yield stability of local oat cultivars. *J. Soil Sci. Plant Nutr.* **2018**, *18*, 269–281. [CrossRef]
100. Asfaw, M.D. Effects of animal manures on growth and yield of maize (*Zea mays* L.). *J. Plant Sci. Phytopathol.* **2022**, *6*, 033–039. [CrossRef]
101. Karimuna, L.; Halim, A.A.; Hasanuddin, L. Growth and yields of two varieties of maize (*Zea mays* L.) intercropped with peanut (*Arachys hypogaea* L.) applied by bokashi plus fertilizer between the rows of teak trees based agroforestry system. *IOP Conf. Ser. Earth Environ. Sci.* **2022**, *951*, 012041. [CrossRef]
102. Zhang, G.; Shen, D.; Ming, B.; Xie, R.; Hou, P.; Xue, J.; Wang, K.; Li, S. Optimizing Planting Density to Increase Maize Yield and Water Use Efficiency and Economic Return in the Arid Region of Northwest China. *Agriculture* **2022**, *12*, 1322. [CrossRef]
103. Calamai, A.; Masoni, A.; Marini, L.; Dell'acqua, M.; Ganugi, P.; Boukail, S.; Benedettelli, S.; Palchetti, E. Evaluation of the Agronomic Traits of 80 Accessions of Proso Millet (*Panicum miliaceum* L.) under Mediterranean Pedoclimatic Conditions. *Agriculture* **2020**, *10*, 578. [CrossRef]
104. Santra, D.K.; Heyduck, R.F.; Baltensperger, D.D.; Graybosch, R.A.; Nelson, L.A.; Frickel, G.; Nielsen, E. Registration of 'Plateau' Waxy (Amylose-Free) Proso Millet. *J. Plant Regist.* **2015**, *9*, 41–43. [CrossRef]
105. Vetriventhan, M.; Upadhyaya, H.D. Diversity and trait-specific sources for productivity and nutritional traits in the global proso millet (*Panicum miliaceum* L.) germplasm collection. *Crop J.* **2018**, *6*, 451–463. [CrossRef]
106. Sutardi; Pertiwi, M.D.; Praptana, R.H.; Anda, M.; Purwaningsih, H.; Triastono, J.; Kristamtini; Susanto, U.; Widyayanti, S.; Kabarsih, M.; et al. Increasing Yield and Economic Value of Upland Rice Using Inorganic Fertilizer and Poultry Manure in Dryland. *Agronomy* **2022**, *12*, 2829. [CrossRef]
107. Promchote, P.; Wang, S.-Y.S.; Yoon, J.-H.; Johnson, P.G.; Creech, E.; Shen, Y.; Yao, M.-H. On the Changing Cool Season Affecting Rice Growth and Yield in Taiwan. *Agronomy* **2022**, *12*, 2625. [CrossRef]
108. Bečka, D.; Bečková, L.; Kuchtová, P.; Cihlář, P.; Pazderů, K.; Mikšík, V.; Vašák, J. Growth and yield of winter oilseed rape under strip-tillage compared to conventional tillage. *Plant Soil Environ.* **2021**, *67*, 85–91. [CrossRef]
109. Balodis, O.; Gaile, Z. Oilseed Rape (*Brassica napus* ssp. Oleifera) Seed Yield Depending on Several Agro-Ecological Factors. *Renew. Energy Energy Effic.* **2012**, 39–44. Available online: https://llufb.llu.lv/conference/Renewable_energy_energy_efficiency/Latvia_Univ_Agriculture_REEE_conference_2012-39-44.pdf (accessed on 12 March 2023).
110. Brown, J.K.M.; Beeby, R.; Penfield, S. Yield instability of winter oilseed rape modulated by early winter temperature. *Sci. Rep.* **2019**, *9*, 6953. [CrossRef] [PubMed]

111. Rajković, D.; Marjanović Jeromela, A.; Pezo, L.; Lončar, B.; Zanetti, F.; Monti, A.; Kondić Špika, A. Yield and Quality Prediction of Winter Rapeseed-Artificial Neural Network and Random Forest Models. *Agronomy* **2022**, *12*, 58. [CrossRef]
112. Wei, M.C.F.; Molin, J.P. Soybean Yield Estimation and Its Components: A Linear Regression Approach. *Agriculture* **2020**, *10*, 348. [CrossRef]
113. Mandić, V.; Dorđević, S.; Dordević, N.; Bijelić, Z.; Krnjaja, V.; Petričević, M.; Brankov, M. Genotype and Sowing Time Effects on Soybean Yield and Quality. *Agriculture* **2020**, *10*, 502. [CrossRef]
114. Didorenko, S.V.; Abugaliyeva, A.I.; Yerzhebayeva, R.S.; Plotnikov, V.G.; Ageyepko, A.V. Monitoring quality and yield capacity of soybean varieties during the creation of various ecotypes in Kazakhstan. *AGRIVITA J. Agric. Sci.* **2021**, *43*, 558–568. [CrossRef]
115. Tziouvalekas, M.; Tigka, E.; Kargiotidou, A.; Beslemes, D.; Irakli, M.; Pankou, C.; Arabatzi, P.; Aggelakoudi, M.; Tokatlidis, I.; Mavromatis, A.; et al. Seed Yield, Crude Protein and Mineral Nutrients of Lentil Genotypes Evaluated across Diverse Environments under Organic and Conventional Farming. *Plants* **2022**, *11*, 3328. [CrossRef]
116. Prysiazhniuk, O.; Mostoviak, I.; Yevchuk, Y.; Tkachenko, H.; Prokopenko, E.; Kononenko, E.; Prykhodko, V.; Vyshnevska, L.; Poltoretska, L. Lentil Yield Performance and Quality as Affected by Moisture Supply. *Ecol. Eng. Environ. Technol.* **2022**, *23*, 25–33. [CrossRef]
117. Swargiary, S.; Umesha, C.; Dwivedi, N. Influence of Spacing and Zinc Levels on Growth and Yield of Lentil (*Lens culinaris*). *Biol. Forum Int. J.* **2021**, *13*, 114–117.
118. Amare, T.; Bazie, Z.; Alemu, E.; Alemayehu, B.; Tenagne, A.; Kerebh, B.; Taye, Y.; Awoke, A.; Feyisa, T.; Kidanu, S. Yield of potato (*Solanum tuberosum* L.) increased by more than two-folds through nitrogen and phosphorus fertilizers in the highlands of North-Western Ethiopia. *Heliyon* **2022**, *8*, e11111. [CrossRef] [PubMed]
119. Placide, R.; Theophile, N.; Vandamme, E.; Claude, N.J.; Thiago, M. Yield performance, adaptability and processing qualities of pre-release potato clones under different Rwandan agro-ecologies. *CABI Agric. Biosci.* **2022**, *3*, 40. [CrossRef]
120. Nyiraneza, J.; Bizimungu, B.; Messiga, A.J.; Fuller, K.D.; Fillmore, S.A.E.; Jiang, Y. Potato yield and phosphorus use efficiency of two new potato cultivars in New Brunswick, Canada. *Can. J. Plant Sci.* **2017**, *97*, 5. [CrossRef]
121. Kun, Á.; Kolozsvári, I.; Potyondi, L.; Bartos, Á.S.; Bozán, C. Root Yield and Sugar Accumulation in Sugarbeet and Fodder Beet According to Irrigation Water Quality. *Agronomy* **2022**, *12*, 2174. [CrossRef]
122. Varga, I.; Loňcarić, Z.; Kristek, S.; Kulundžić, A.M.; Rebekić, A.; Antunović, M. Sugar Beet Root Yield and Quality with Leaf Seasonal Dynamics in Relation to Planting Densities and Nitrogen Fertilization. *Agriculture* **2021**, *11*, 407. [CrossRef]
123. Esmaeili, R.; Mohammadian, R.; Abad, H.H.S.; Mohammadi, G.N. Improving quantity and quality of sugar beet yield using agronomic methods in summer cultivation. *Plant Soil Environ.* **2022**, *68*, 347–357. [CrossRef]
124. Heydarzadeh, S.; Gitari, H.; Rahimi, A.; Khiavi, H.K.; Maitra, S.; Hosseinpour, A. Yield and Quality Traits of Field-grown Sugar Beet (*Beta vulgaris* L.) in Response to Foliar Application of Micronutrients and Different Levels of Manure. *Int. J. Bioresour. Sci.* **2021**, *8*, 103–112. [CrossRef]
125. Nahar, N.; Mazed, H.E.M.K.; Moonmoon, J.F.; Mehraj, H.; Jamal Uddin, A.F.M. Growth and Yield Response of Carrot (*Daucus carota* L.) to Phosphorus. *Int. J. Bus. Soc. Sci. Res.* **2014**, *1*, 125–128.
126. Tegen, H.; Jembere, M. Influences of spacing on yield and root size of carrot (*Daucus carota* L.) under ridge-furrow production. *Open Agric.* **2021**, *6*, 826–835. [CrossRef]
127. França, A.R.S.; Borcioni, E.; Paixão, C.A.; Araujo, R.S.; Campos, R.V.; Cruz, S.P. Growth and yield of carrot inoculated with Bacillus subtilis and Pseudomonas fluorescens. *Rev. Colomb. Cienc. Hortícolas* **2020**, *14*, 385–392. [CrossRef]
128. Haque, M.S.; Haque, A.F.M.Z.; Hossain, B.; Eakram, N.N.M.S. Effect of Potassium Fretilization to Increase the Yield of Carrot (*Daucus carota* L.). *Int. J. Bioinform. Biol. Sci.* **2019**, *7*, 15–19. [CrossRef]
129. Ma, S.; He, F.; Tian, D.; Zou, D.; Yan, Z.; Yang, Y.; Zhou, T.; Huang, K.; Shen, H.; Fang, J. Variations and determinants of carbon content in plants: A global synthesis. *Biogeosciences* **2018**, *15*, 693–702. [CrossRef]
130. OECD/FAO. OECD-FAO Agricultural Outlook. Paris: OECD Agriculture Statistics, Agricultural Outlook 2019–2028. 2019. Available online: https://www.oecd.org/agriculture/oecd-fao-agricultural-outlook-2019/ (accessed on 10 March 2023).
131. Statistics Poland Agriculture in 2019. Available online: https://stat.gov.pl/en/topics/agriculture-forestry/agriculture/agriculture-in-2019,4,16.html (accessed on 1 March 2023).
132. Grogan, D.; Frolking, S.; Wisser, D.; Prusevich, A.; Glidden, S. Global gridded crop harvested area, production, yield, and monthly physical area data circa 2015. *Sci. Data* **2022**, *9*, 15. [CrossRef] [PubMed]
133. Mwafulirwa, L.; Baggs, E.M.; Russell, J.; George, T.; Morley, N.; Sim, A.; Cantó, C.D.L.F.; Paterson, E. Barley genotype influences stabilization of rhizodeposition-derived C and soil organic matter mineralization. *Soil Biol. Biochem.* **2016**, *95*, 60–69. [CrossRef]
134. IPCC. *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*; IPCC: Geneva, Switzerland, 2019. Available online: https://www.ipcc.ch/report/srccl/ (accessed on 1 March 2023).
135. Willett, W.; Rockström, J.; Loken, B.; Springmann, M.; Lang, T.; Vermeulen, S.; Garnett, T.; Tilman, D.; DeClerck, F.; Wood, A.; et al. Food in the anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems. *Lancet* **2019**, *393*, 447–492. [CrossRef] [PubMed]
136. Neupane, D.; Adhikari, P.; Bhattarai, D.; Rana, B.; Ahmed, Z.; Sharma, U.; Adhikari, D. Does Climate Change Affect the Yield of the Top Three Cereals and Food Security in the World? *Earth* **2022**, *3*, 45–71. [CrossRef]

137. Habiyaremye, C.; Matanguihan, J.B.; D'Alpoim Guedes, J.; Ganjyal, G.M.; Whiteman, M.R.; Kidwell, K.K.; Murphy, K.M. Proso millet (*Panicum miliaceum* L.) and its potential for cultivation in the Pacific Northwest, US. A review. *Front. Plant Sci.* **2017**, *7*, 1961. [CrossRef]
138. Bandyopadhyay, T.; Muthamilarasan, M.; Prasad, M. Millets for next generation climate-smart agriculture. *Front. Plant Sci.* **2017**, *8*, 1266. [CrossRef]
139. Lychuk, T.; Moulin, A.; Lemke, R.; Gossen, B.; Leeson, J.; Kirk, A.; Johnson, E.; Olfert, O.; Brandt, S.; Thomas, A. Effects of crop inputs, diversity, environment, and terrain on yield in an 18-yr study in the semi-arid Canadian Prairies. *Can. J. Plant Sci.* **2017**, *97*, 715–730. [CrossRef]
140. Lychuk, T.E.; Hill, R.L.; Izaurralde, R.C.; Momen, B.; Thomson, A.M. Evaluation of climate change impacts and effectiveness of adaptation options on nitrate loss, microbial respiration, and soil organic carbon in the Southeastern USA. *Agric. Syst.* **2021**, *193*, 103210. [CrossRef]
141. Sage, R.F.; Zhu, X.-G. Exploiting the engine of C4 photosynthesis. *J. Exp. Bot.* **2011**, *62*, 2989–3000. [CrossRef] [PubMed]
142. Jansson, C.; Wullschleger, S.D.; Udaya, C.K.; Tuskan, G.A. Phytosequestration: Carbon biosequestration by plants and the prospects of genetic engineering. *Bioscience* **2010**, *60*, 685–696. [CrossRef]
143. Abdullahi, A.C.; Siwar, C.; Shaharudin, M.I.; Anizan, I. *Carbon Capture, Utilization and Sequestration*; Agarwal, R.K., Ed.; IntechOpen: London, UK, 2018. [CrossRef]
144. Li, P.; Brutnell, T.P. Setaria viridis and Setaria italica, model genetic systems for the Panicoid grasses. *J. Exp. Bot.* **2011**, *62*, 3031–3037. [CrossRef] [PubMed]
145. Kell, D.B. Large-scale sequestration of atmospheric carbon via plant roots in natural and agricultural ecosystems: Why and how. *Philos. Transact. R. Soc. B Biol. Sci.* **2012**, *367*, 1589–1597. [CrossRef]
146. Paustian, K.; Collier, S.; Baldock, J.; Burgess, R.; Creque, J.; DeLonge, M.; Dungait, J.; Ellert, B.; Frank, S.; Goddard, T.; et al. Quantifying carbon for agricultural soil management: From the current status toward a global soil information system. *Carbon. Manag.* **2019**, *10*, 567–587. [CrossRef]
147. Jansson, C.; Faiola, C.; Wingler, A.; Zhu, X.-G.; Kravchenko, A.; de Graaff, M.-A.; Ogden, A.J.; Handakumbura, P.P.; Werner, C.; Beckles, D.M. Crops for Carbon Farming. *Front. Plant Sci.* **2021**, *12*, 636709. [CrossRef]
148. Paustian, K.; Larson, E.; Kent, J.; Marx, E.; Swan, A. Soil C Sequestration as a Biological Negative Emission Strategy. *Front. Clim.* **2019**, *1*, 8. [CrossRef]
149. Ort, D.R.; Merchant, S.S.; Alric, J.; Barkan, A.; Blankenship, R.E.; Bock, R.; Croce, R.; Hanson, M.R.; Hibberd, J.M.; Long, S.P. Redesigning photosynthesis to sustainably meet global food and bioenergy demand. *Proc. Natl. Acad. Sci. USA* **2015**, *112*, 8529–8536. [CrossRef]
150. Kromdijk, J.; Głowacka, K.; Leonelli, L.; Gabilly, S.T.; Iwai, M.; Niyogi, K.K.; Long, S.P. Improving photosynthesis and crop productivity by accelerating recovery from photoprotection. *Science* **2016**, *354*, 857. [CrossRef]
151. South, P.F.; Cavanagh, A.P.; Liu, H.W.; Ort, D.R. Synthetic glycolate metabolism pathways stimulate crop growth and productivity in the field. *Science* **2019**, *363*, 9077. [CrossRef]
152. White, A.C.; Rogers, A.; Rees, M.; Osborne, C.P. How can we make plants grow faster? A source-sink perspective on growth rate. *J. Exp. Bot.* **2016**, *67*, 31–45. [CrossRef] [PubMed]
153. Jansson, C.; Vogel, J.; Hazen, S.; Brutnell, T.; Mockler, T. Climate-smart crops with enhanced photosynthesis. *J. Exp. Bot.* **2018**, *69*, 3801–3809. [CrossRef]
154. Chang, T.G.; Zhu, X.-G. Source-sink interaction: A century old concept under the light of modern molecular systems biology. *J. Exp. Bot.* **2017**, *68*, 1002. [CrossRef] [PubMed]
155. Serrago, R.A.; Alzuleta, I.; Savin, R.; Slafer, G.A. Understanding grain yield responses to source-sink ratios during grain filling in wheat and barley under contrasting environments. *Field Crops Res.* **2013**, *150*, 42–51. [CrossRef]
156. Pe'er, G.; Zinngrebe, Y.; Hauck, J.; Schindler, S.; Dittrich, A.; Zingg, S.; Tscharntke, T.; Oppermann, R.; Sutcliffe, L.M.E.; Sirami, C.; et al. Adding Some Green to the Greening: Improving the EU's Ecological Focus Areas for Biodiversity and Farmers. *Conserv. Lett.* **2017**, *10*, 517–530. [CrossRef]
157. Chahal, I.; Vyn, R.J.; Mayers, D.; van Eerd, L.L. Cumulative impact of cover crops on soil carbon sequestration and profitability in a temperate humid climate. *Sci. Rep.* **2022**, *10*, 13381. [CrossRef]
158. Poeplau, C.; Don, A. Carbon sequestration in agricultural soils via cultivation of cover crops—A meta-analysis. *Agric. Ecosyst. Environ.* **2015**, *200*, 33–41. [CrossRef]
159. Wendling, M.; Charles, R.; Herrera, J.; Amossé, C.; Jeangros, B.; Walter, A.; Büchi, L. Effect of species identity and diversity on biomass production and its stability in cover crop mixtures. *Agric. Ecosyst. Environ.* **2019**, *281*, 81–91. [CrossRef]
160. Kwiatkowski, C.A.; Harasim, E.; Staniak, M. Effect of catch crops and tillage systems on some chemical properties of loess soil in a short-term monoculture of spring wheat. *J. Elem.* **2020**, *25*, 35–43. [CrossRef]
161. Bruce, R.R.; Langdale, G.W.; West, L.T. Modification of soil characteristics of degraded soil surfaces by biomass input and tillage affecting soil water regime. *Soil Sci.* **1990**, *6*, 17–21.
162. Lal, R.; Regnier, E.; Eckert, D.J.; Edwards, W.M.; Hammond, R. *Expectation of Cover Crops for Sustainable Agriculture*; Soil and Water Conservation Society: Jackson, TN, USA, 1991; pp. 21–25. Available online: https://www.researchgate.net/publication/246134638_Expectations_of_cover_crops_for_sustainable_agriculture (accessed on 1 March 2023).

163. Biernat, L.; Taube, F.; Vogeler, I.; Reinsch, T.; Kluß, C.; Loges, R. Is organic agriculture in line with the EU-Nitrate directive? On-farm nitrate leaching from organic and conventional arable crop rotations. *Agric. Ecosyst. Environ.* **2020**, *298*, 106964. [CrossRef]
164. Harasim, E.; Antonkiewicz, J.; Kwiatkowski, C.A. The Effects of Catch Crops and Tillage Systems on Selected Physical Properties and Enzymatic Activity of Loess Soil in a Spring Wheat Monoculture. *Agronomy* **2020**, *10*, 334. [CrossRef]
165. Kwiatkowski, C.A.; Harasim, E. Chemical Properties of Soil in Four-Field Crop Rotations under Organic and Conventional Farming Systems. *Agronomy* **2020**, *10*, 1045. [CrossRef]
166. Kwiatkowski, C.A.; Wesołowski, M.; Pałys, E.; Kraska, P.; Haliniarz, M.; Nowak, A.; Andruszczak, S.; Kwiecińska-Poppe, E. *Aspekty Proekologicznego Gospodarowania w Agroekosystemach. [Aspects of Pro-Ecological Management in Agroecosystems]*; Perfekta info: Lublin, Poland, 2014; p. 165. (In Polish)
167. Böldt, M.; Taube, F.; Vogeler, I.; Reinsch, T.; Kluß, C.; Loges, R. Evaluating Different Catch Crop Strategies for Closing the Nitrogen Cycle in Cropping Systems—Field Experiments and Modelling. *Sustainability* **2021**, *13*, 394. [CrossRef]
168. Klages, S.; Aue, C.; Reiter, K.; Heidecke, C.; Osterburg, B. Catch Crops in Lower Saxony—More Than 30 Years of Action against Water Pollution with Nitrates: All in Vain? *Agriculture* **2022**, *12*, 447. [CrossRef]
169. Żuk-Gołaszewska, K.; Wanic, M.; Orzech, K. The role of catch crops in in the field plant production—A review. *J. Elem.* **2019**, *24*, 575–587. [CrossRef]
170. Gentsch, N.; Boy, J.; Batalla, J.D.K.; Heuermann, D.; Von Wirén, N.; Schweneker, D.; Feuerstein, U.; Groß, J.; Bauer, B.; Reinhold-Hurek, B.; et al. Catch crop diversity increases rhizosphere carbon input and soil microbial biomass. *Biol. Fertil. Soils* **2020**, *56*, 943–957. [CrossRef]
171. Pawłowski, L.; Kwiatkowski, C.A.; Harasim, E.; Klikocka-Wiśniewska, O.; Cel, W.; Kujawska, J. Environmental Benefits of Catch Crops Cultivation. *Chem. Didact. Ecol. Metrol.* **2021**, *26*, 109–121. [CrossRef]
172. Pawłowski, L.; Pawłowska, M.; Kwiatkowski, C.A.; Harasim, E. The Role of Agriculture in Climate Change Mitigation—A Polish Example. *Energies* **2021**, *14*, 3657. [CrossRef]
173. Cerdà, A.; Franch-Pardo, I.; Novara, A.; Sannigrahi, S.; Rodrigo-Comino, J. Examining the Effectiveness of Catch Crops as a Nature-Based Solution to Mitigate Surface Soil and Water Losses as an Environmental Regional Concern. *Earth Syst. Environ.* **2022**, *6*, 29–44. [CrossRef]
174. Kwiatkowski, C.A.; Harasim, E.; Haliniarz, M.; Gawęda, D.; Misztal-Majewska, B.; Chojnacka, S. Chemical composition of stubble crop biomass depending on a crop plant species and tillage system. *J. Elem.* **2019**, *24*, 1371–1381. [CrossRef]
175. Hauggaard-Nielsen, H.; Mundus, S.; Jensen, E.S. Nitrogen dynamics following grain legumes and subsequent catch crops and the effects on succeeding cereal crops. *Nutr. Cycl. Agroecosyst.* **2009**, *84*, 281–291. [CrossRef]
176. Vogeler, I.; Hansen, E.M.; Thomsen, I.K.; Østergaard, H.S. Legumes in catch crop mixtures: Effects on nitrogen retention and availability, and leaching losses. *J. Environ. Manag.* **2019**, *239*, 324–332. [CrossRef] [PubMed]
177. Kwiatkowski, C.A. Rola międzyplonów we współczesnym rolnictwie. [The role of catch crops in modern agriculture]. *Stud. Rap. IUNG-PIB* **2012**, *28*, 79–95. (In Polish)
178. Komainda, M.; Taube, F.; Kluß, C.; Herrmann, A. Above- and belowground nitrogen uptake of winter catch crops sown after silage maize as affected by sowing date. *Eur. J. Agron.* **2016**, *79*, 31–42. [CrossRef]
179. Kwiatkowski, C.A.; Juszczak, J. The response of sweet basil (*Ocimum basilicum* L.) to the application of growth stimulators and forecrops. *Acta Agrob.* **2011**, *64*, 69–76. [CrossRef]
180. Gawęda, D. Yield and yield structure of spring barley (*Hordeum vulgare* L.) grown in monoculture after different stubble crops. *Acta Agrob.* **2011**, *64*, 91–98. [CrossRef]
181. Rinnofner, T.; Friedel, J.K.; De Kruijff, R.; Pietsch, G.; Freyer, B. Effect of catch crops on N dynamics and following crops in organic farming. *Agron. Sustain. Dev.* **2008**, *28*, 551–558. [CrossRef]
182. Hauggard-Nielsen, H.; Ambus, P.; Jensen, E.S. Interspecific competition, N use interference with weeds in pea-barley intercropping. *Field Crops Res.* **2001**, *70*, 101–109. [CrossRef]
183. Selzer, T.; Schubert, S. Water dynamics of cover crops: No evidence for relevant water input through occult precipitation. *J. Agron. Crop Sci.* **2023**, *209*, 422–437. [CrossRef]
184. Gentsch, N.; Heuermann, D.; Boy, J.; Schierding, S.; von Wirén, N.; Schweneker, D.; Feuerstein, U.; Kümmerer, R.; Bauer, B.; Guggenberger, G. Soil nitrogen and water management by winter-killed catch crops. *Soil* **2022**, *8*, 269–281. [CrossRef]
185. Gazoulis, I.; Kanatas, P.; Antonopoulos, N.; Tataridas, A.; Travlos, I. Narrow Row Spacing and Cover Crops to Suppress Weeds and Improve Sulla (*Hedysarum coronarium* L.) Biomass Production. *Energies* **2022**, *15*, 7425. [CrossRef]
186. Heuermann, D.; Gentsch, N.; Guggenberger, G.; Reinhold-Hurek, B.; Schweneker, D.; Feuerstein, U.; Heuermann, M.C.; Groß, J.; Kümmerer, R.; Bauer, B.; et al. Catch crop mixtures have higher potential for nutrient carry-over than pure stands under changing environments. *Eur. J. Agron.* **2022**, *136*, 126504. [CrossRef]
187. Liu, J.; Bergkvist, G.; Ulén, B. Biomass production and phosphorus retention by catch crops on clayey soils in southern and central Sweden. *Field Crops Res.* **2015**, *171*, 130–137. [CrossRef]
188. Talgre, L.; Lauringson, E.; Mekke, A.; Lauk, R. Biomass production and nutrient binding of catch crops. *Zemdirb. Agric.* **2011**, *98*, 251–258.
189. Pawłowski, L.; Pawłowska, M.; Cel, W.; Wang, L.; Li, C.; Mei, T. Characteristic of carbon dioxide absorption by cereals in Poland and China. *Gospod. Surowcami Miner. Min. Resour. Manag.* **2019**, *35*, 165–176. [CrossRef]

190. Cretan, R.; O'Brien, T. Corruption and conflagration: (In) Justice and protest in Bucharest after the *Colectiv* fire. *Urban Geogr.* **2020**, *41*, 368–388. [CrossRef]
191. Rozkrut, D. (Ed.). *Statistical Yearbook of Agriculture 2018*; GUS: Warsaw, Poland, 2018. Available online: https://stat.gov.pl/download/gfx/portalinformacyjny/en/ (accessed on 2 March 2023).
192. Smit, B.; Janssens, B.; Haagsma, W.; Hennen, W.; Adrados, J.; Kathage, J. *Adoption of Cover Crops for Climate Change Mitigation in the EU*; Kathage, J., Perez Dominguez, I., Eds.; Publications Office of the European Union: Luxembourg, 2019; ISBN 978-92-76-11312-6.
193. Pawłowska, M.; Pawłowski, A.; Pawłowski, L.; Cel, W.; Wójcik Oliveira, K.; Kwiatkowski, C.A.; Harasim, E.; Wang, L. Possibility of Carbon Dioxide Sequestration by Catch Crops. *Ecol. Chem. Eng. S* **2019**, *26*, 641–649. [CrossRef]
194. Berazneva, J.; Conrad, J.M.; Guerena, D.T.; Lehman, J.; Woolf, D. Agricultural prodcutivity and soil carbon dynamics: A bioeconomic model. *Am. J. Agric. Econ.* **2019**, *101*, 1021–1046. [CrossRef]
195. Sanderman, J.; Farquharson, R.; Baldock, J.A. Soil Carbon Sequestration Potential: A Review for Australian Agriculture. 2010. Available online: www.csiro.au/resources/Soil-Carbon-Sequestration-Potential-Report.html (accessed on 20 January 2023).
196. Jia, L.; Cheng, P.; Yu, Y.; Chen, S.H.; Wang, C.X.; He, L.; Nie, H.T.; Wang, J.C.; Zhang, J.C.; Fan, B.G.; et al. Regeneration mechanism of a novel high-performance biochar mercury adsorbent directionally modified by multimetal multilayer loading. *J. Environ. Manag.* **2023**, *326 Pt B*, 116790. [CrossRef]
197. Weber, K.; Quicker, P. Properties of biochar. *Fuel* **2018**, *217*, 240–261. [CrossRef]
198. Cheng, H.G.; Jones, D.L.; Hill, P.; Bastami, M.S.; Tu, C.L. Influence of biochar produced from different pyrolysis temperature on nutrient retention and leaching. *Arch. Agron. Soil Sci.* **2018**, *64*, 850–859. [CrossRef]
199. Mandal, S.; Thangarajan, R.; Bolan, N.S.; Sarkar, B.; Khan, N.; Ok, Y.S.; Naidu, R. Biochar-induced concomitant decrease in ammoniavolatilization and increase in nitrogen use efficiency by wheat. *Chemosphere* **2016**, *142*, 120–127. [CrossRef]
200. Hossain, M.Z.; Bahar, M.M.; Sarkar, B.; Donne, S.W.; Ok, Y.S.; Palansooriya, K.N.; Kirkham, M.B.; Chowdhury, S.; Bolan, N. Biochar and its importance on nutrient dynamics in soil and plant. *Biochar* **2020**, *2*, 379–420. [CrossRef]
201. Guo, Y.; Wang, X.J.; Li, X.L.; Wang, J.P.; Xu, M.G.; Li, D.W. Dynamics of soil organic and inorganic carbon in the cropland of upper Yellow River Delta, China. *Sci. Rep.* **2016**, *6*, 36105. [CrossRef] [PubMed]
202. Grafahrend-Belau, E.; Junker, A.; Eschenroeder, A.; Muller, J.; Schreiber, F.; Junker, B. Multiscale metabolic modeling: Dynamic flux balance analysis on a whole-plant scale. *Plant Physiol.* **2013**, *163*, 637–647. [CrossRef] [PubMed]
203. Lakshmanan, M.; Cheung, C.Y.M.; Mohanty, B.; Lee, D.Y. Modeling rice metabolism: From elucidating environmental effects on cellular phenotype to guiding crop improvement. *Front. Plant Sci.* **2016**, *7*, 1795. [CrossRef]
204. Töpfer, N.; Braam, T.; Shameer, S.; Ratcliffe, R.G.; Sweetlove, L.J. Alternative crassulacean acid metabolism modes provide environment-specific water-saving benefits in a leaf metabolic model. *Plant Cell* **2020**, *32*, 3689–3705. [CrossRef]
205. Matthews, M.L.; Marshall-Colon, A. Multiscale plant modeling: From genome to phenome and beyond. *Emerg. Top. Life Sci.* **2021**, *5*, ETLS20200276. [CrossRef]
206. Bloom, A.J.; Chapin, F.S.; Mooney, H.A. Resource limitation in plants—An economic analogy. *Annu. Rev. Ecol. Syst.* **1985**, *16*, 363–392. [CrossRef]
207. Poorter, H.; Nagel, O. The role of biomass allocation in the growth response of plants to different levels of light, CO2, nutrients and water: A quantitative review. *Aust. J. Plant Physiol.* **2000**, *27*, 595–607. [CrossRef]
208. Lorenz, K.; Lal, R.; Shipitalo, M.J. Chemical stabilization of organic carbon pools in particle size fractions in no-till and meadow soils. *Biol. Fertil. Soils* **2008**, *44*, 1043–1051. [CrossRef]
209. Kaiser, C.; Kilburn, M.R.; Clode, P.L.; Fuchslueger, L.; Koranda, M.; Cliff, J.B.; Solaiman, Z.M.; Murphy, D. Exploring the transfer of recent plant photosynthates to soil microbes: Mycorrhizal pathway vs direct root exudation. *New Phytol.* **2015**, *205*, 1537–1551. [CrossRef] [PubMed]
210. Pendall, E.; Mosier, A.R.; Morgan, J.A. Rhizodeposition stimulated by elevated CO_2 in a semiarid grassland. *New Phytol.* **2004**, *162*, 447–458. [CrossRef]
211. Phillips, R.P.; Meier, I.C.; Bernhardt, E.S.; Grandy, A.S.; Wickings, K.; Finzi, A.C. Roots and fungi accelerate carbon and nitrogen cycling in forests exposed to elevated CO_2. *Ecol. Lett.* **2012**, *15*, 1042–1049. [CrossRef]
212. Kravchenko, A.N.; Guber, A.K.; Razavi, B.S.; Koestel, J.; Quigley, M.Y.; Robertson, G.P.; Kuzyakov, Y. Microbial spatial footprint as a driver of soil carbon stabilization. *Nat. Commun.* **2019**, *10*, 12000. [CrossRef]
213. Bardgett, R.D.; Mommer, L.; De Vries, F.T. Going underground: Root traits as drivers of ecosystem processes. *Trends Ecol. Evol.* **2014**, *29*, 692–699. [CrossRef]
214. Postma, J.A.; Kuppe, C.; Owen, M.R.; Mellor, N.; Griffiths, M.; Bennett, M.J.; Lynch, J.P.; Watt, M. OPENSIMROOT: Widening the scope and application of root architectural models. *New Phytol.* **2017**, *215*, 1274–1286. [CrossRef]
215. Voges, M.J.E.E.E.; Bai, Y.; Schulze-Lefert, P.; Sattely, E.S. Plant-derived coumarins shape the composition of an Arabidopsis synthetic root microbiome. *Proc. Natl. Acad. Sci. USA* **2019**, *116*, 12558–12565. [CrossRef]
216. Bengtson, P.; Barker, J.; Grayston, S.J. Evidence of a strong coupling between root exudation, C and N availability, and stimulated SOM decomposition caused by rhizosphere priming effects. *Ecol. Evol.* **2012**, *2*, 1843–1852. [CrossRef]
217. Keiluweit, M.; Bougoure, J.J.; Nico, P.S.; Pett-Ridge, J.; Weber, P.; Kleber, M. Mineral protection of soil carbon counteracted by root exudates. *Nat. Clim. Chang.* **2015**, *5*, 588–595. [CrossRef]

218. Naveed, M.; Brown, L.K.; Raffan, A.C.; George, T.S.; Bengough, A.G.; Roose, T.; Sinclair, I.; Koebernick, N.; Cooper, L.; Hackett, C.A.; et al. Plant exudates may stabilize or weaken soil depending on species, origin and time. *Eur. J. Soil Sci.* **2017**, *68*, 806–816. [CrossRef] [PubMed]
219. Lange, M.; Eisenhauer, N.; Sierra, C.A.; Bessler, H.; Engels, C.; Griffiths, R.I.; Mellado-Vázquez, P.G.; Malik, A.A.; Roy, J.; Scheu, S.; et al. Plant diversity increases soil microbial activity and soil carbon storage. *Nat. Commun.* **2015**, *6*, 7707. [CrossRef] [PubMed]
220. Zhang, L.M.; Zhuang, Q.L.; He, Y.J.; Yu, D.S.; Zhao, Q.Y.; Shi, X.Z.; Xing, S.H.; Wang, G.X. Toward optimal soil organic carbon sequestration with effects of agricultural management practices and climate change in Tai-Lake paddy soils of China. *Geoderma* **2016**, *275*, 28–39. [CrossRef]
221. Baggs, E.M.; Watson, C.A.; Rees, R.M. The fate of nitrogen from incorporated cover crop and green manure residues. *Nutr. Cycl. Agroecosystems* **2000**, *56*, 153–163. [CrossRef]
222. European Commission 2020: Peatlands for LIFE. Available online: https://cinea.ec.europa.eu/system/files/2021-02/PeatlandsforLIFE-19062020.pdf (accessed on 24 February 2023).
223. European Commission 2021: Reviewing the Contribution of the Land Use, Land-use Change and Forestry Sector to the Green Deal: Workshop IV Report: Carbon Farming in the CAP Strategic Plans. European Commission. Available online: https://ec.europa.eu/clima/sites/default/files/forests/docs/20210525_workshop_iv_report_en.pdf (accessed on 24 February 2023).
224. Economist, T. Sucking up Carbon. Greenhouse Gases Must be Scrubbed from the Air. 2017. Available online: http://www.economist.com/news/briefing/21731386-cutting-emissions-will-not-be-enough-keep-global-warming-check-greenhouse-gases-must-be?frsc=dg%7Ce (accessed on 25 December 2022).
225. Marks, A.B. (Carbon) Farming Our Way Out of Climate Change. *Denv. L. Rev.* **2020**, *497*, 97. Available online: https://scholar.law.colorado.edu/faculty-articles/1294 (accessed on 24 February 2023).
226. Wiese, L.; Wollenberg, E.; Alcántara-Shivapatham, V.; Richards, M.; Shelton, S.; Hönle, S.E.; Heidecke, C.; Madari, B.E.; Chenu, C. Countries' commitments to soil organic carbon in nationally determined contributions. *Clim. Policy* **2021**, *21*, 1005–1019. [CrossRef]
227. Gosnell, H.; Charnley, S.; Stanley, P. Climate change mitigation as a co-benefit of regenerative ranching: Insights from Australia and the United States. *Interface Focus* **2020**, *10*, 20200027. [CrossRef]
228. Chitakira, M.; Ngcobo, N.Z.P. Uptake of climate smart agriculture in peri-urban areas of South Africa's economic hub requires up-scaling. *Front. Sustain. Food Syst.* **2021**, *5*, 706738. [CrossRef]