soil systems

Review

Conservation Agriculture as a Sustainable System for Soil Health: A Review

Belén Cárceles Rodríguez [1], Víctor Hugo Durán-Zuazo [1,*], Miguel Soriano Rodríguez [2], Iván F. García-Tejero [3], Baltasar Gálvez Ruiz [1] and Simón Cuadros Tavira [4]

[1] IFAPA Centro "Camino de Purchil", Camino de Purchil s/n, 18004 Granada, Spain
[2] Dpto. Agronomía, Universidad de Almería, Ctra, Sacramento s/n, La Cañada de San Urbano, 04120 Almeria, Spain
[3] IFAPA Centro "Las Torres", Carretera Sevilla-Alcalá del Río km 12.2, Alcalá del Río, 41200 Sevilla, Spain
[4] Dpto. Ingeniería Forestal, Universidad de Córdoba, Campus de Rabanales, Ctra.Madrid-Cadiz, Km.396, 14071 Cordoba, Spain
* Correspondence: victorh.duran@juntadeandalucia.es; Tel.: +34-900-156-000

Abstract: Soil health is a term used to describe the general state or quality of soil, and in an agroecosystem, soil health can be defined as the ability of the soil to respond to agricultural practices in a way that sustainably supports both agricultural production and the provision of other ecosystem services. Conventional agricultural practices cause deterioration in soil quality, increasing its compaction, water erosion, and salinization and decreasing soil organic matter, nutrient content, and soil biodiversity, which negatively influences the productivity and long-term sustainability of the soil. Currently, there are many evidences throughout the world that demonstrate the capability of conservation agriculture (CA) as a sustainable system to overcome these adverse effects on soil health, to avoid soil degradation and to ensure food security. CA has multiple beneficial effects on the physical, chemical, and biological properties of soil. In addition, CA can reduce the negative impacts of conventional agricultural practices on soil health while conserving the production and provision of soil ecosystem services. Today, agricultural development is facing unprecedented challenges, and CA plays a significant role in the sustainability of intensive agriculture. This review will discuss the impact of conservation agricultural practices on soil health and their role in agricultural sustainability.

Keywords: conservation agriculture; indicators; soil health; soil quality; sustainability

Citation: Cárceles Rodríguez, B.; Durán-Zuazo, V.H.; Soriano Rodríguez, M.; García-Tejero, I.F.; Gálvez Ruiz, B.; Cuadros Tavira, S. Conservation Agriculture as a Sustainable System for Soil Health: A Review. *Soil Syst.* **2022**, *6*, 87. https://doi.org/10.3390/soilsystems6040087

Academic Editors: José L. S. Pereira and Vítor João Pereira Domingues Martinho

Received: 18 October 2022
Accepted: 18 November 2022
Published: 23 November 2022

1. Introduction

Soil is the surface material that covers most land, containing inorganic particles and organic matter and supplying structural support to agricultural plants, being thus their source of nutrients and water. Agriculture today faces a double-sided challenge—on the one hand, the urgent need to provide food to a growing population, and on the other hand, to do so in a sustainable way [1], without compromising the provision of ecosystem services by the soil, such as carbon sequestration, nutrient supply, and water cycle regulation.

Sustainable agriculture is a difficult concept to define, since the environmental, social and economic impacts of agriculture are diverse and interact with one another [2]. In general, it can be stated that sustainable crop production systems are those that respect the environment, improve efficiency in the use of resources and promote human well-being [3]. They are those food production practices that integrate ecological, biological, physical and chemical principles, without harming the environment, as opposed to unsuitable agricultural practices [4].

Soil health is the state of the soil in relation to its potential ability to maintain its biological productiveness, strengthen environmental quality, and foster plant and animal health. Sustainable agriculture can be defined as agriculture that can be practiced in a productive and profitable way without affecting the health of the soil [5]. Figure 1 shows the main functions exerted by soil. Today, soil health is threatened all over the world. Some of the main threats to soil are erosion, compaction, salinization, nutrient depletion, pollution, and/or overgrazing [6].

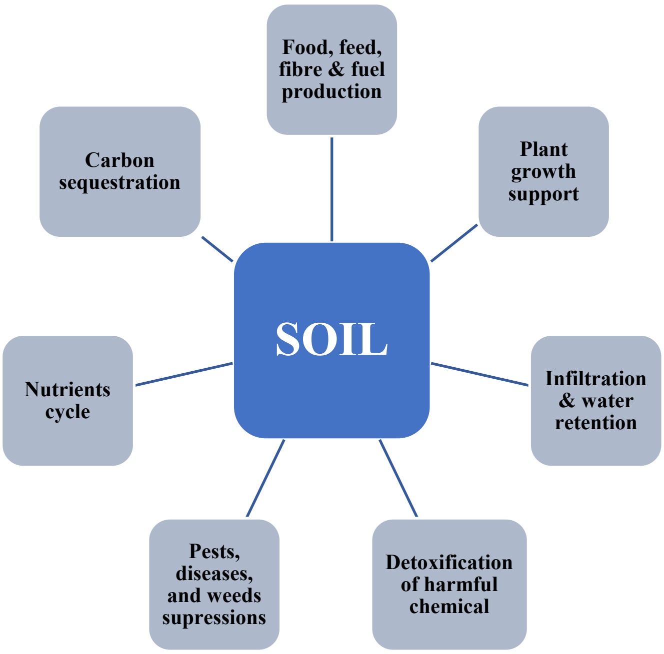

Figure 1. Main functions of soil (Adapted from [7]).

On the other hand, land degradation and deterioration of soil fertility are two of the main causes of the decline in the agricultural productivity of agroecosystems. The intensification of agriculture deteriorates the soil quality, and its negative effects have increased in the past few decades. The aim of conventional agriculture is to produce the highest possible yield of crops by the application of synthetic products, energy inputs, and a number of other industrial products. Biodiversity, soil fertility, and ecosystem health are compromised under conventional systems.

The intensive use of machinery and chemical inputs increases compaction, erosion, and soil salinization and decreases the content of organic matter and soil nutrients, which negatively influences the soil's productivity and long-term sustainability. The degradation of agricultural soil under different cropping systems is a socioeconomic and environmental problem that must be urgently addressed, particularly considering that climate change is expected to have a strong negative impact on food production, as was defined by Smith and Gregory [8]. CA practices are a useful strategy for climate change mitigation and adaptation [9,10]. CA allows slowing down or reducing greenhouse gas emissions and improving carbon sequestration in the soil [11]. The application of CA practices can improve the properties of soil, increasing its resilience to drought, and improving water and nutrient use efficiency. These improvements are essential to maintain the sustainability of agricultural production and mitigate the impacts of climate change on food production [12,13]. To reduce these negative impacts of agricultural systems and guarantee their long-term sustainability, management systems that improve or conserve soil quality are crucial [14]. To this end, agronomic practices of conservation agriculture (CA) are promoted. Figure 2 shows the environmental impacts of conventional agriculture and the benefits of CA on the soil system.

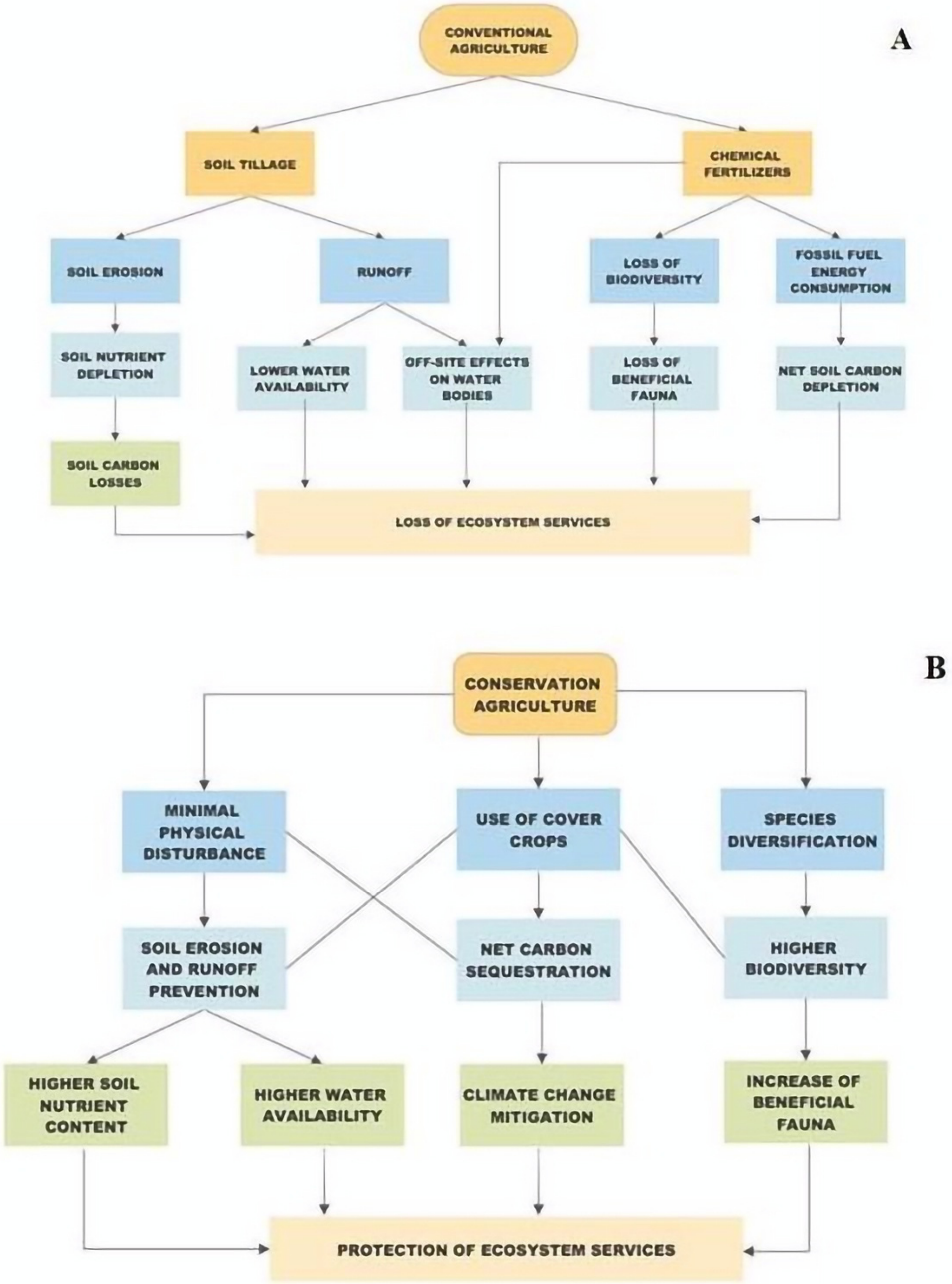

Figure 2. Environmental impacts of conventional agriculture (**A**) and the benefits of conservation agriculture (**B**) on soils.

In this review, we examine and describe advancements in the implementation of conservation agriculture measures as a sustainable system, focusing on their impacts on soil health and its role in supporting the suitable management of land, while fostering food security.

2. Conservation Agriculture

The Food and Agriculture Organization (FAO) defines CA as an agroecosystem management system to ensure food security and improve profits while preserving environmental resources.

Food security, as defined by the United Nations' Committee on World Food Security, means that all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life. Currently almost 800 million people do not have access to enough food, more than 2 billion people experience deficiencies in key micronutrients, and approximately 60% of people in developing countries are food insecure [15]. In addition, it is foreseeable that in the coming decades, the growth of the world population, climate change and environmental impacts will aggravate the problem. The magnitude of the problem globally means that food security is related to all of the Sustainable Development Goals (SDGs) of the United Nations.

Conservation agriculture is an agroecosystem management approach that can be considered as one of the main ways to achieve the sustainability of agriculture, allowing the goal of greater protection while protecting the environment [16]. CA emerged in the 1930s in the USA to combat soil degradation due to water and wind erosion [17]. CA is characterized by the application of three interlinked principles implemented with locally adapted practices, together with other complementary agricultural practices [18]. These three principles are:

(1) Continuous minimum mechanical soil disturbance;
(2) Permanent soil organic cover with crop residues and/or cover crops;
(3) Species diversification through varied crop rotations, sequences, and associations.

The concomitant application of these three individual principles constitutes the classical definition of CA. However, many smallholder farmers cannot apply these three rules at the same time, and CA defined as a fixed package is not often adapted to the particular conditions of small farms. The application separately or in tandem of these components has been shown to have potential benefits, as was reported by many authors [19–21]. However, some of these authors argue that it is necessary to move from the strict definition of CA as a fixed set of three components to talking about conservation practices, which encompass a variety of options for sustainable agricultural intensification [22,23].

CA constitutes the central nucleus of FAO's new sustainable agricultural intensification strategy [24]. According to the FAO, CA is applicable to all "agricultural landscapes and land uses with locally adapted practices", which implies a series of economic, agronomic, and environmental benefits. In this sense, CA is a viable option for the sustainable intensification of agricultural land and obtaining profitable production [25,26].

In 2015/2016, CA was practiced worldwide in 180 M ha (about 12.5% of the total global cropland), an increase of 69% compared to 2008/2009. This growth has been greater in recent years. From 1999 to 2003, the area under CA increased by an average of 8.3 M ha per year [27]. The adoption of CA is not uniform in all regions or among all types of farms. It is generalized in large farms in North America, Australia, and Brazil. In contrast, adoption by smallholder farmers accounts for only 0.3% of the farmland worldwide under CA [28]. Globally, the total CA area is still comparatively small in relation to the total arable land using conventional tillage (CT). As pointed out by Kassam et al. [27], it is expected that large areas of agricultural lands in Asia, Africa, Europe, and Central America will adopt CA in the coming years. The low adoption of CA in developing countries can be attributed in part to the fact that it is a complex system, coupled with insufficient technical knowledge and capacity of farmers. In this context, political and institutional support is essential through incentives for farmers to adopt CA practices and technical support from experts [21].

To increase the implementation of CA techniques and the benefits derived from it, site-specific practices must be designed [22,25,29]. An important constraint is the limited availability in most developing countries of affordable and suitable machinery for no-till seeding, especially for small- and medium-scale farmers [30]. The development and availability of equipment that allows for sufficient germination of crops planted in no-tillage systems, with mulch in the soil, and that can adapt to small- and large-scale farmers should be improved [31]. Therefore, CA is an alternative to enhance productivity and food security, while preserving natural resources and reducing the negative externalities of traditional agricultural practices [32]. Moreover, the CA system can significantly improve the resistance to changing climate conditions in cropping systems [33,34]. In this context, conservation tillage is applied as an alternative to CT in order to alleviate water erosion impacts, reduce production costs, and maintain soil quality [35,36]. The positive effects of minimum tillage on soil quality, environment, and soil water conservation as compared to non-tilled soils in rainfed plantations were highlighted by Jacobs et al. [37] and Busari et al. [38]. Table 1 summarizes the main economic/agronomic and environmental benefits derived from CA practices.

Table 1. Main economic/agronomic and environmental benefits generated by conservation agriculture.

Economic/Agronomic	Environmental
Labor and fuel savings	Lower CO_2 emissions
Cost and time savings	Erosion and surface runoff reductions
Yield gains	Improvement of soil properties
Reduced fertilizer expenditures	Increase in soil biodiversity
Weed control	Increase in microbial activity
Lower irrigation needs	Less pollution of downstream water
Lower risk of pest and disease outbreaks	

Adapted from [31,39].

The cover cropping system as a technique of CA is an essential part of crop rotations in many regions worldwide, dispensing a wide range of benefits and ecosystem services such as N supply and retention [40], weed control [41], soil nematode control [42], water retention [43], and mitigation of nitrate leaching [44]. In addition, in the long term, cover crops can build up soil organic carbon and N [45,46] and lower net N_2O and CO_2 emissions, thus contributing climate change mitigation services [47]. Cover cropping can improve soil organic carbon stocks and potentially promote climate stability and food security, as was reported by Minasny et al. [48]. Similarly, according to Garcia-Tejero et al. [49], who examined Mediterranean rainfed agroecosystems, the use of CA techniques to enhance soil water management and soil carbon storage is vital.

On the other hand, Daryanto et al. [50], in a global quantitative synthesis of ecosystem services from cover crops, reported the suitability of their implementation. Despite the potential benefits of cover crops to improve soil conditions, this measure can add to the complexity of farming operations. According to Clark et al. [51], in the case of hairy vetch (*Vicia villosa* Roth.), which can provide a considerable amount of N demanded by the subsequent crop (maize), a late cover crop harvest is recommended because this allows for higher N accumulation in their biomass and for better synchronization of N release from the decomposing cover crop and maize N uptake [52]. In contrast, the early harvest of the cover crop may be suitable in circumstances where the rainfall amount is low and the depletion of soil moisture reserves by cover crops is a drawback [53].

The CA practices result in soil quality improvement only gradually, and benefits come about only with time. According to Stagnari et al. [54], between 3 to 7 years may be needed for all of the benefits to take hold. Therefore, because long periods are often required before changes in the soil can be detected, studies of CA must be based on long-term research and trials. This transition phase is crucial to ensure the success of the adoption of CA practices. In the initial transition years, problems can arise, such as more difficult weed management [55], lower productivity [56], etc., which can discourage farmers and lead them to abandon these practices.

3. Soil Health

Soil has been receiving increasing political and scientific interest in recent times, given its capability to provide various ecosystem services that contribute to the United Nations Sustainable Development Goals and to the European Union Green Deal [57]. Concepts such as soil health and soil quality are used to refer to this soil capability. The terms soil health and soil quality are often used interchangeably. In fact, the distinction between the two concepts is not clear. According to Laishram et al. [58], soil health refers to a broader concept—the capacity of soil to function as a living system to support plant, animal, and human life. Conversely, soil quality concerns the capacity of a specific kind of soil to sustain a particular use, such as crop production. Bonfante et al. [57] established the following distinction between the two terms: "Soil health is the actual capacity of a particular soil to function, contributing to ecosystem services", while "soil quality is the inherent capacity of a particular soil to function, contributing to ecosystem services". Both concepts, soil health and quality, are used to monitor soil status, analyze the influence of soil management on agricultural sustainability, and direct decision making to avoid degradation [4]. Figure 3 summarizes the management principles and the benefits of soil health.

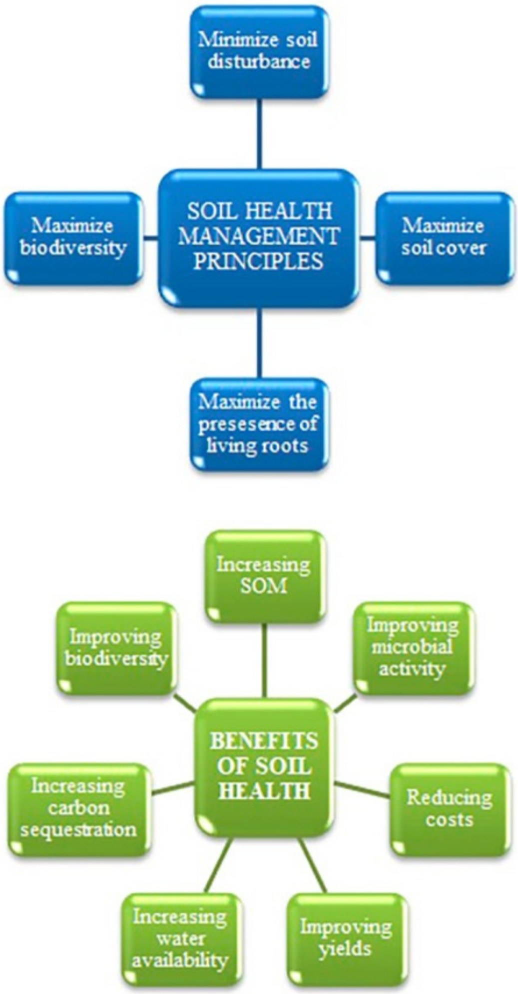

Figure 3. Management principles and benefits of soil health.

Although the concept of soil health emerged in the early 2000s, it is still evolving. It is not an easy concept to define, since soil is an extremely complex ecosystem, as was stated before. There are numerous definitions in the literature. According to Doran and Zeiss [14], soil health is "the capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health". The U.S. Department of Agriculture (USDA) [59] defines soil health as "the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans". Yang et al. [60] defined it as "the capacity of soil to function, within ecosystem boundaries, to sustain crop and animal productivities, maintain or enhance environmental sustainability, and improve human health worldwide".

According to Kibblewhite et al. [5], healthy agricultural soil is "capable of supporting the production of food and fiber, to a level and with a quality sufficient to meet human requirements, together with continued delivery of other ecosystem services that are essential for maintenance of the quality of life for humans and the conservation of biodiversity". According to Wang and Hooks [61], soil health can be defined as having six main characteristics: (i) high biological diversity, (ii) high community stability that can provide resilience and self-recovery to chemical and biological disturbance, (iii) the ability to maintain the integrity of nutrient cycling and energy flow, (iv) the suppression of multiple pests and pathogens, (v) the ability to improve plant health, and (vi) the maintenance of water and air quality.

All of these definitions are conceptual, since they attempt to define what healthy soil is without defining how it is measured. The operational definitions establish a series of key indicators of soil health. It is essential to include indicators of physical, chemical, and biological properties when assessing soil health, as was stated by Bünemann et al. [62]. Ideally, indicators of soil health should be related to relevant soil processes and sensitive to changes in management practices and environmental conditions [60]. There is no universal set of ideal soil characteristics, and their interpretation is always context-dependent [63].

Finally, the concept of soil health can be approached from a "reductionist" or "integrated" point of view. The first is based on estimating the state of the soil using a set of individual indicators of specific soil properties: physical, chemical, and biological. The integrated approach recognizes the complexity of the soil system and the existence of interactions between the different properties and processes of the soil; therefore, soil health is more than simply the sum of a set of specific indicators [5]. According to this integrative approach, the indicators selected to establish soil health must be the result of interactions of the biota with the physicochemical properties of the soil [64]. Thus, healthy soils are crucial for the integrity of agricultural lands to maintain, or recover from perturbations resulting from, agricultural operations, particularly those regarding soil management.

Soil Health Indicators

Knowing and understanding the state of soil health is essential to guarantee the sustainable management of agroecosystems. Soil health is a complex functional concept and cannot be measured directly in the field or laboratory; it can only be inferred indirectly by measuring soil indicators [65]. These indicators are measurable soil parameters that influence soil function and ecosystem services [66].

In general, soil health indicators can be classified as physical, chemical, or biological, although these categories are not always clearly delimited, since there are many soil properties that result from the interaction of multiple processes [67]. Evidently, no single indicator can encompass all processes and parameters of soil health, nor is it feasible (or necessary) to measure all soil attributes. Therefore, it is necessary to select a minimum dataset (MDS) including physical, chemical, and biological parameters of the soil. Establishing a minimal dataset, representative of total data, minimizes costs and efforts in soil health assessment. Table 2 shows an MDS for soil health assessment with the indicators more commonly used.

The desired features of soil health indicators are that they be: (i) easy to measure; (ii) measurable with practical, rapid, and inexpensive measurement methods; (iii) sensitive to variations in management; (iv) relevant to soil ecosystem functions; and (v) informative for management [14,68].

Table 2. Minimum data set (MDS) for soil health assessments.

Key Soil Health Parameters	Reason
BIOLOGICAL	
N mineralization	Capacity of the soil to supply N for crop growth
Microbial biomass	Source and/or drain of C and nutrients
Microbial activity	Related to the availability of nutrients and biogeochemical cycles
Soil respiration	Indicator for biological activity and organic matter
CHEMICAL	
Organic carbon	Important for soil structure and fertility, and water-holding capacity
Bio-available nutrient	Potential of nutrients to support plant development
pH	Availability of nutrients
CEC	Soil's availability to supply plant nutrients
EC	Related to soil structure, infiltration and crop development
Potential pollutants	Potentially harmful for plant growth and plant–soil system health
PHYSICAL	
Penetration resistance	Related to infiltration capacity and erosion and runoff processes
Aggregation	Indicator of soil structure and erosion protection
Infiltration	Indicator for erosion and runoff
Depth to hardpan	Roots growth potential
Texture	Important for soil water and nutrient transfer and retention
Water-holding capacity	Sufficient moisture to support plant growth

CEC, Cation exchange capacity; EC, Electrical conductivity. Compiled by authors from different sources [67,69,70].

Several methods can be used to define an appropriate MDS, including statistical tools (principal component analysis, multiple correlation, etc.), uncertain sets, expert opinion, and farmer/local knowledge [66]. Once the MDS has been established, linear and/or non-linear techniques can be applied to interpret the soil indicators. The non-linear scoring method is more representative of system function than the linear method but is more labor-intensive and requires more knowledge [71]. When individual indicators are scored, they can be integrated into a general index, which can be used to guide management decisions toward promoting the long-term sustainability of the soil resource [72]. These indices have an integrating character, combining multidimensional data on the physical, chemical, and biological properties of soil into a one-dimensional measure of soil health [59]. Many soil health indices can be found in the literature: additives, weighted, decision support system, integrated quality index, Nemoro quality index, etc. [71,73].

The benefits of using these indices are clear—they provide a unique value of soil health, which allows direct comparison between different soils [39]. They are also a decision tool that can help identify the most sustainable management practices [71]. However, they also have drawbacks. For example, the diversity of existing methodologies to build this one-dimensional index means that the resulting value for this index may vary between methods, making it difficult to interpret the results [39]. Furthermore, their use can sometimes give an overly simplified interpretation of the response of the complex agroecosystem to natural or anthropogenic disturbances [60].

4. Impact of Conservation Agriculture on Soil Health

CA measures have been put forward to restore or maintain major soil functions (C cycling and transformation, nutrient cycling, and soil structure maintenance), performing well in terms of crop yield, economic return, greenhouse gas emission mitigation, biodiversity conservation, and soil health improvement. Contrarily, there is an almost general consensus that certain practices of conventional agriculture to increase agricultural production have detrimental effects on the health of the soil. CA is proposed as an alternative to conventional management to ensure sustainability in the provision of ecosystem services through the soil [74], which can improve soil properties and associated processes [13,34].

The total impact of CA systems on soil health varies from location to location and is dependent on site-specific soil and climatic conditions, the amount of time operating under a CA system, features of CA practices (types of cover crops, intensity of the crop rotation, etc.), and the training and experience of farmers [34,70,75].

4.1. Influence on Soil Physical Properties

Traditional agriculture through CT provokes a significant alteration of physical soil properties, such as degradation of the structure, compaction problems, soil bulk density, soil penetration resistance, etc. CA is able to reduce these negative effects of CT. Some of the most important parameters of soil physical health are described in the following sections.

4.1.1. Soil Structure

Soil structure is an important parameter in the sustainability of agroecosystems, due to its role in physical, chemical, and biological dynamics of soil, and determines its resistance to degradation by water erosion. Aggregate stability against different stresses (rainfall, tillage, etc.) is a useful measure to determine soil structural stability.

According to Bronick and Lal [76], soil structure can be significantly modified through management practices. Soil structural development can be enhanced by management systems that reduce soil disturbances, increase organic matter inputs, increase plant cover, and improve soil fertility. In this sense, one of the major negative impacts of conventional long-term tillage is the deterioration of the soil structure due to the reduction in soil organic matter [34].

There is a positive correlation between the mean weight diameter of soil aggregates and total organic carbon content [77,78]. The soil organic matter (SOM) promotes macroaggregate formation; meanwhile, soil aggregates improve the physical protection of organic matter [79]. Higher aggregate stability under CA is the result of the interaction of various factors: (i) the retention of organic residue on the soil surface protects soil aggregates from raindrop impact and avoids soil compaction [80]; (ii) decomposing organic matter increases the aggregation process [81]; (iii) no soil disturbance increases fungal populations and the persistence of root networks that encourage the stability of the aggregates [82]; and (iv) reducing soil disturbance in CA systems allows the development of a more stable soil structure than in CT systems [83]. Numerous studies have reported an improvement in the stability of soil aggregates due to the application of CA practices [84–86]. In a study in Zambia, CA practices with residue retention and crop rotation showed higher aggregate stability (41–45%) compared with conventional ploughing practices (24%) [87]. This improvement in the stability of the aggregates is a function of the type of soil. Thus, Nyamangara et al. [88] reported a greater increase in the stability of the aggregates due to CA practices in soils high in clay (18.1%) than in soils low in clay (9%), compared to CT. The increase in aggregate stability due to CA practices is greater in the topsoil layer, decreasing with depth. Zhang et al. [89] reported a greater increase in the stability of soil aggregates in the surface layer (0–20 cm) than in the subsurface layer (20–40 cm) in treatments with straw return compared to treatments without straw. A study by Eze et al. [90] with a long-term experiment found that maize-based CA systems result in significant changes to soil hydraulic properties that correlate with improved soil structure. The findings showed increases of 5–15% in total porosity, 0.06–0.22 cm/min in Ksat (saturated hydraulic conductivity), 3–7% in fine pores for water storage, and 3–6% in plant-available water capacity. Furthermore, according to these authors, the maize monocrop under CA practices had an impact on soil hydraulic properties comparable to that of the maize–legume associations.

These improvements in the soil structure, due to CA practices, promote other beneficial effects on the soil, such as higher infiltration rates, greater protection against erosion, increased water-holding capacity, improved habitats to support microbial activity, etc.

4.1.2. Bulk Density

The bulk density is one of the most common physical parameters to assess the impact of tillage and crop residue on agricultural soils, as it is an indicator of the soil's compaction and reflects the soil's ability to function in terms of structural support, water and solute movement, and soil aeration. High bulk densities cause root impedance and lead to poor crop emergence. There is no consensus regarding the effect of CA on soil bulk density, as some studies reported a higher soil bulk density with CA compared to CT [91,92], while others have not found significant differences [86,93] or reported lower soil bulk density in CA in comparison to CT [88,94]. These differences in bulk density in the different trials may be due in part to the typology of the farm. Greater topsoil bulk density recorded in studies on large farms in the USA or Australia can be the result of compaction due to heavy no-till machinery used, but this does not occur in smallholder farms in developing countries, where cultivation is performed manually or with animal draft power [95].

In a global meta-analysis, Li et al. [96] claimed an average increased bulk density of 1.4% in a no-tillage (NT) system with residue retention compared with CT. However, they also concluded that the greatest soil compaction value in conservation tillage practices was below the threshold value that limits plant growth.

According to Mondal et al. [97], no significant differences in bulk density were found in soil depth up to 15 cm after the implementation of CA. However, a greater bulk density was determined in a traditional rice–wheat cropping system than in treatments with CA at soil depth of 15–30 cm. Generally, bulk density was greater for CA than CT for soil depths within the plow layer [13,98]. However, in the top few centimeters in NT, the accumulation of crop residues and soil organic carbon (SOC) on the soil surface led to a lower bulk density [99]. Sometimes, the amount of residue is not enough to limit the increase in bulk density under no-tillage systems. In these cases, the residues can be shredded, thus increasing the covered area and mitigating the hardening of the soil [98].

The effect of conservation tillage systems (minimum/reduced tillage and no tillage) on the apparent density of the soil is not immediate; it is necessary that a few years elapse from the conversion from CT to reduce it [100]. The crop residue incorporation into the soil in conservation tillage plays a pivotal role in decreasing bulk density. In this sense, Nyamadzawo et al. [101] attributed lower bulk density in CA systems to the presence of higher levels of organic matter, which tends to improve soil structure and increase porosity. In contrast, Mondal et al. [102] reported a similar bulk density under CT and NT systems.

According to Islam and Reeder [103], soil bulk density at 0 to 15 and 15 to 30 cm depths under long-term NT decreased significantly compared to CT. At 0 to 15 cm depth, the greatest difference compared to CT occurs with 35 years of continuous zero tillage. The bulk density at depths of 15–30 cm decreased linearly over the years of NT. This decrease in bulk density is associated with an increase in total soil porosity. In a long-term study of maize (*Zea mays* L.) based crop rotations, the bulk density under CA practices (zero tillage and permanent raised beds) was reduced by 4.3–6.9% in soil depths of 0–30 cm compared with CT. In deeper soil layers (30–60 cm), differences between management systems were non-significant [104].

4.1.3. Surface Seal and Soil Crust

Bare soil in conventional systems leads to increased surface seal and crust formation due to the lack of protection against the impact of raindrops. The impact of rainfall causes the breakdown of soil aggregates and the release of finer particles, which are redistributed by the near-surface and fill the most superficial pores. This process causes sealing and surface waterproofing, decreasing water infiltration and, consequently, enhancing the runoff and soil loss [105]. Surface sealing has a negative impact on the physical characteristics of soil, which ultimately affects crop yield [106].

The presence of crop residues in CA practices can help protect the surface of the soil from raindrop impact and prevent surface sealing. In structurally unstable soils or regions where crusting is a serious problem, the maintenance of adequate surface cover is paramount to avoid surface sealing and crust formation [107]. When CA is practiced in the absence of effective soil mulch cover, surface sealing may occur. Usón and Poch [108] showed that reduced tillage did not reduce crust formation in Mediterranean conditions, due to the difficulty of establishing an effective ground cover. In certain circumstances, the quantities of biomass produced and retained in CA systems can be insufficient to avoid soil crusting and compaction [109], but increasing residue above a threshold can have no effect because of sufficient raindrop impact interception [110]. According to Page et al. [111], the surface sealing, due to the inadequate residue cover and the lack of tillage, particularly in drier regions, can be one cause of yield loss in CA systems. In situations where little surface cover from crop residue is available, the creation of surface roughness using strategic tillage is a viable option to break soil crusts, improve water infiltration, and reduce runoff [112].

Thus, a permanent soil surface cover by crop residues significantly reduces surface sealing [113]. Various studies report on the preventive effect against surface sealing in CA exerted by crop residues on the soil surface, protecting the soil from the direct impact of raindrops [114,115]. In this sense, Castellanos-Navarrete et al. [84] reported that in CA systems, soil crusts were not present on the soil surface; however, soil under CT with poor aggregate stability showed soil crust formation.

4.1.4. Soil Compaction

Soil compaction is a form of physical degradation that consists of the densification of the soil, which often results in the destruction of the soil structure; a reduction in biological activity, porosity, and permeability; an increased risk of erosion; a restriction on root development; and, consequently, decreased crop performance. On farmland, the traffic of heavy agricultural machinery is the main cause of soil compaction, and its magnitude increases with the number and intensity of tillage operations and when these are carried out in inappropriate soil moisture conditions. The influence of the machinery is so important that "controlling in-field traffic" is considered a component of CA. Recommended practices include bed planting that reduces compaction by confining traffic to the furrow bottoms [116], or the application of fertilizers at the time of seedbed preparation or seeding to reduce machinery transit [117].

In the long term, tillage promotes soil compaction and the formation of a plough pan in the sub soil. Crop rotation, cover crops, and the addition of crop residues in CA systems can reduce soil compaction. Mondal et al. [118] reported a reduction in the subsurface compaction by CA systems, with a soil penetration resistance significantly less in the 15–30 cm layer under CA. This can have a positive impact on root morphology, which can contribute to increased crop yield. According to Hamza and Anderson [119], increasing the SOM through the retention of crop residues and crop rotations that include plants with deep, strong taproots can delay or prevent soil compaction. The use of root crops in cover crops can significantly reduce soil compaction. In this sense, Islam and Reeder [103] showed that oilseed radish significantly decreased compaction to about 75 cm, with an average improvement effect of about 40% compared with soil between the rows. Chen and Weil [120] reported that the use of cover crops improved maize root penetration in compacted soils and increased the availability of surface soil water. In a study in India, Parihar et al. [104] reported that the CA practices of NT and permanent raised beds reduced the penetration resistance by 15.9 and 30.7%, respectively, compared to CT in maize rotations.

According to Holland [17], there is evidence that the long-term use of conservation tillage can, in certain situations, lead to soil compaction. Similarly, Munkholm et al. [121] concluded that direct drilling provoked the compaction of the arable layer below seeding depth on sandy loam. Thus, the long-term viability of conservation tillage techniques depends on a proper crop rotation [122] and/or the use of strategic or occasional tillage in soils under NT [123,124].

4.1.5. Soil Moisture Content

Water scarcity is one of the greatest challenges facing humanity in the coming decades [125]. CA practices improve soil moisture availability, especially under low-rainfall conditions and could contribute to maintaining crop yield in a changing climate scenario [126]. In this sense, several studies have reported a greater availability of water in CA systems with respect to CT [85,127–129]. Residue retention and cover crops in CA systems improve infiltration [96] and reduce runoff rates [127] and evaporation losses [130,131], as they protect soil from direct contact with solar radiation and act as a barrier to air flow, contributing to higher soil moisture.

No-till practices and residue cover improved soil–water relations in a study in Malawi, with an average increase in soil water content of 22 and 18 mm in NT and CA, respectively, compared to CT [132]. A meta-analysis carried out by Zhao et al. [133] concluded that crop residue retention led to an increase in soil water content by 5.9% compared with crop residue removal. In a rice system study, NT with surface residue and minimum tillage with residue incorporation had higher soil moisture than CT with residue removed [134]. Similarly, Ghosh et al. [127] reported that soil moisture conservation was 108% higher under CA than conventional agriculture plots. Mondal et al. [135] showed that the soil water content was 14% higher in CA relative to CT in the sub-surface layer (15–30 cm), while in other layers, there were no significant differences. A study by Chalise et al. [136] with a corn–soybean (*Glicine max* L.) system highlighted that the use of cover crops with residue returned improved the soil's hydrological properties and increased soil volumetric water content and soil water storage. In maize crops in the sub-humid and semi-arid regions of Kenya, NT with residue retention significantly increased soil water content compared to CT [137]. According to Sindelar et al. [138], residue removal decreased plant-available water by 32% in soil depth of 0 to 5 cm and by 21% in soil depth of 5 to 10 cm. In this context, Li et al. [96] reported that NT with residue retention increased soil-available water capacity by 10.2% compared with NT without residue retention. Similarly, Choudhary et al. [139], in a pearl millet (*Cenchrus americanus* L.)–mustard (*Brassica juncea* L.) rotation system in rainfed semi-arid regions, reported higher soil water content throughout the season in plots with residue retention than in the no-residue plots.

In irrigated plantations, crop residues conserve soil moisture and delay irrigation timing, allowing farmers to save irrigation water. In this sense, Balwinder-Singh et al. [140] found that the use of residue mulch of 8 t ha^{-1} in irrigated wheat led to saving 75 mm of irrigation water. Comparably, Gupta and Sayre [141] reported that NT practices allowed saving between 13 and 21% of irrigation water compared to CT systems. Assefa et al. [142] highlighted that CA practices with a drip irrigation system lessened water needs by about 14–35% for various crops. In irrigated onion and garlic plantations in Ethiopia, CA plots received 49 mm less water than CT treatment [143]. In addition, Jat et al. [144] showed that a CA-based maize–wheat system decreased irrigation water use by 64% compared to conventional management.

Based on field observations, many meta-analysis studies have contrasted the effects of different tillage practices on determining crop production, evapotranspiration, and water-use efficiency (WUE) [122,145–147]. Evidently, CA practices enhance WUE, as the findings by Lu [148] suggested that crop residue return can increase crop yields and WUE. In a study in a semi-arid region of China, Sun et al. [149] stated that conservation tillage significantly enhanced WUE and crop yield with respect to CT. According to Das et al. [150], experimental plots under CA practices had significantly higher WUE and significantly lower water use than CT. That is, the zero tillage with planting on permanent broad beds and residues treatment had higher WUE than the CT. Moreover, zero tillage with planting on permanent broad beds and residues treatment had higher WUE than zero tillage with planting on permanent narrow beds and residues. Thus, CA practices improve water productivity due to their water harvesting and water conservation effects [151].

Although most studies have found positive effects of residue retention on soil water, some negative consequences can also occur in certain environments, such as in rainfed areas. Cover crops in sloping lands with rainfed fruit crops do not result in economic return; however, the environmental return is highly important [152,153]. Cover crops, however, compete for resources (plant nutrients and water) with the trees, which can lead to a decline in productivity [154,155]. In other words, the cover crop benefits are more weather-specific than site-specific because when precipitation is low or not properly distributed, the water reduction after cover crops could have a negative effect on the cash crop growth and yield. In sloping olive orchards, a greater available soil water content was found under a non-tillage system with plant strips (barley and native vegetation) of 4 m width than for a non-tillage system without plant strips, particularly beneath the tree canopies [156]. In addition, Castellini et al. [157] reported the positive influence on soil hydraulic function of minimum tillage compared to non-tilled soil on olive plantations. In this context, Abazi et al. [158], examining rainfed olive orchards, determined that the use of cover crops in a Mediterranean environment has a negative impact on olive transpiration (25% average reduction), although this impact can be attenuated by early-date killing of the cover crop in the middle of March.

Contrarily, in high-rainfall areas, the greater retention of soil moisture under CA can also lead to waterlogging, with associated negative effects on crop growth and yield [91,159,160].

4.1.6. Water Runoff and Soil Loss

Conventional agriculture promotes runoff and soil loss by causing soil compaction, crusting, and surface sealing, and by decreasing porosity. In contrast, CA is associated with a reduction in soil erosion [161] (Figure 4), among other benefits. In particular, in rainfed sloping lands in Mediterranean environments, the crop residue retention and cover crops in CA systems protect the soil surface from raindrop impact and reduce the detachment, displacement, movement, and deposition of soil particles, which causes soil sealing and crust formation [162]. Furthermore, cover crops and their residues slow the velocity of agricultural runoff along the slope, improving infiltration and preventing soil erosion [163].

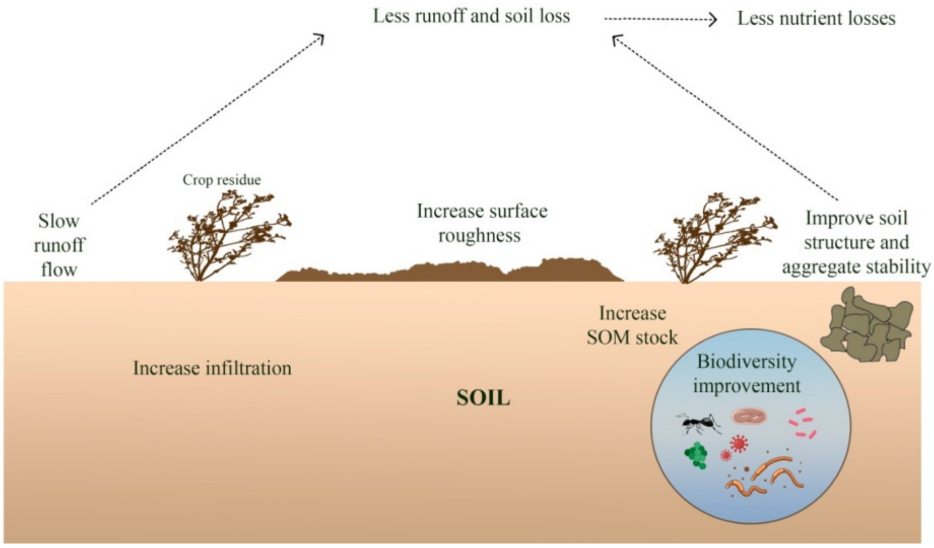

Figure 4. Effect of conservation agriculture on water erosion.

According to Thierfelder and Wall [164], plots with reduced tillage and surface residue retention had less runoff and soil erosion than conventionally tilled plots. Under semiarid rainfed conditions in western India, Kurothe et al. [165] reported that NT reduced runoff by 16.2% and soil loss by 37.2% compared to CT. Panachuki et al. [166] reported a significant reduction in runoff and soil loss in an NT system with soybean residues, compared to an NT system without residues. The retention of residues on the soil surface exerted a greater protective effect than their incorporation into the soil. In an experiment in northern Ethiopia with a wheat (*Triticum* sp.)–teff (*Eragrostis tef*) rotation, after 3 years, soil loss and runoff were significantly lower (5.2 t ha^{-1} and 46.3 mm) in permanent raised beds with 30% standing stubble compared to CT without surface residue (24.2 t ha^{-1} and 98.1 mm) [167]. Ghosh et al. [127] reported that mean runoff coefficients and soil loss with CA plots were ~45% less and ~54% less than conventional agriculture plots, respectively. The efficiency by which surface residues control runoff and soil losses increased with the amount of residue. In this context, Ranaivoson et al. [168] reported that residue levels of 1.5 to 4.5 t dry matter ha^{-1} decreased water runoff by about 50%, and residue amounts of 2 to 4 t dry matter ha^{-1} reduced soil erosion by about 80% compared to bare soil. The amount of residue necessary to reduce runoff and soil loss varies depending on the slope of the field and the intensity or amount of rainfall [169].

According to Du et al. [170], conservation practices decrease surface runoff and erosion, on average, by 67 and 80%, respectively, compared with conventional practices; the use of cover crops is what most reduces erosion and runoff. In northern Ethiopia, permanent raised beds with contour furrows at 60–70 cm intervals significantly reduced runoff and soil loss compared to traditional ploughing, with 255 and 653 m^3 ha^{-1} runoff and 4.7 t ha^{-1} and 19.5 t ha^{-1} soil loss, respectively [171]. In another study in Ethiopia, CA practices also reduced erosion and runoff. CA registered a runoff coefficient of 18.8% and a soil loss of 14.4 t ha^{-1} yr^{-1}, while for plain tillage, these parameters were 30.4% and 35.4 t ha^{-1} yr^{-1}, respectively [172].

Terracing is one of the oldest techniques for the conservation of water and soil in mountainous regions; terraces are built along contour lines to increase the arable surface area. Deng et al. [173] pointed out that these structures provide many ecosystem services, including the control of runoff and sediment by over 41.9 and 52%, respectively, and the improvement of crop yield and soil water content by 44.8 and 12.9%, respectively. In this context, the implementation of cover crops in the taluses of orchard terraces is a key factor for preventing their collapse by water erosion, lessening the runoff, soil loss, and pollution risk in low lands [174,175].

The rainfed plantations in the Mediterranean mountains with traditional practices provoke high soil erosion rates, compromising their long-term sustainability. Francia et al. [176] evaluated erosion rates by the effect of NT, CT, and cover crops in olive (*Olea europea* L.) orchards of 25.6, 5.7, and 2.1 t ha^{-1} yr^{-1}, respectively. Similarly, Gómez et al. [177] determined the soil erosion values for NT, CT, and cover crops as 6.9, 2.9, and 0.8 t ha^{-1} yr^{-1}, respectively. Recently, Cárceles et al. [178] reported that the strategies based on CA proved to be effective. The combination of minimum tillage with plant strips in almond (*Prunus dulcis* L.) and vineyard (*Vitis vinifera* L.) orchards was a more efficient practice in terms of water erosion control than only minimum tillage, averaging declines in soil erosion and runoff rates of 36 and 39%, respectively. Similarly, for olive crops, the association of minimum tillage and plant strips compared to a no-tillage system was able to reduce both soil erosion and runoff rates by 36%. Thus, the implementation of soil management measures based on cover crops is essential for hillslopes and low-fertility soils, encouraging their sustainability.

4.1.7. Soil Temperature

Soil temperature is an important property that affects crop growth and development and impacts numerous soil physical, chemical, and biological processes. Cover crops and retention of residues in CA systems can help moderate and stabilize the fluctuations in soil temperature during the crop growth period as compared to systems with bare soil [34], which can be especially important in regions with large fluctuations in temperatures [179]. The magnitude of variation in soil temperature due to management is higher in the soil top layer, decreasing in the lower layers [180]. Rai et al. [181] reported that the CA practices with mulching were effective for the reduction in soil temperature fluctuations with depth.

Moreover, crop residue retention on the soil surface reflects sunlight and isolates soil from high temperatures and thus reduces evaporative losses of water. The effect of residues on the soil temperature changes depending on the color of the residues. According to Sharratt and Campbell [182], dark residues resulted in higher mid-day temperatures compared to lighter-colored residues. Retention of residues on the soil surface in CA systems decreases daytime soil temperature [183]. Li et al. [184] reported that the crop residue remaining on the soil surface in conservation tillage systems can lessen the soil temperature change because surface residue both increases the reflection of incident solar radiation and acts as an insulating barrier between the soil surface and the warmer or colder atmospheric air above [185]. In this context, lower maximum soil temperature and higher minimum soil temperature in the 0–5 cm surface soil layer were recorded under minimum tillage with mulch treatments, compared to the CT with no-mulch treatment [186]. According to Gupta et al. [187], a zero-tillage system with residue cover had a lower soil temperature than a zero-tillage system without residue and moldboard ploughing. Guzman and Al-Kaisi [188] also reported warmer soil temperatures when crop residues were removed. In the summer season, Oliveira et al. [189] reported that daytime soil temperature in a zero-tillage system with residue retention was 2–8 °C lower than that in the conventional tillage system.

In addition, this lower soil temperature under CA systems in hot regions can help improve plant growth and crop yield [190]. In cooler climates, however, reduced soil temperature from residue cover may be a disadvantage because it can delay seed germination and plant maturity and negatively affect yield [91,191]. In this sense, Chen et al. [192] reported that straw retention decreased soil temperature in spring and delayed the development of winter wheat up to 7 days, on average reducing the final grain yield by 7% compared to systems without straw retention. To address this issue and attempt to adapt this soil management system to temperate zones, the withdrawal of residues from the seed strip has been suggested [191,193].

Tillage operations can also affect soil temperature by changing soil surface microtopography, as inclined ridge surfaces absorbed about 10% more solar radiation than flat surfaces, according to Radke [194]. Additionally, Shen et al. [195] claimed that tillage had significant effects on soil temperature in 10 of 15 weekly periods, with the temperatures of non-tilled soils being 0–1.5 °C lower than those of moldboard plough soils when residue was not returned in the previous autumn. Moreover, the ridge tillage showed no clear advantage over non-tilled soils in increasing soil temperature.

Finally, other studies reported an increase in soil temperature due to stubble retention [196], which helps crops survive during the cold winter and reduces emergence time, improving crop productivity. Kahimba et al. [197] showed that in the Canadian prairies, the presence of a crop cover or perennial vegetation resulted in relatively warmer soil profile temperatures and shallower depth of frozen soil layers. Moreover, according to Al-Darby et al. [198], despite the delay in the growing season due to the lower soil temperature in the CA systems, there was no reduction in dry matter and corn grain yield due to the greater amount of accumulated water.

4.2. Influence on Soil Chemical Properties

Agronomical practices may change soil chemical properties and thus fertility. The responses of soil chemical fertility to tillage practices and the magnitude of these changes depend on several factors: soil type, cropping system, climate, fertilizer application, and management practices. Long-term tillage causes severe SOM depletion in agroecosystems and can lead to soil degradation. In contrast, CA practices increase chemical quality by improving the SOC storage and nutrient dynamics. The impacts of CA techniques on some of the most relevant soil chemical properties are presented in the following sections.

4.2.1. Soil Organic Carbon

SOM is a keystone indicator of soil quality because it is linked to other physical, chemical, and biological soil quality indicators [199], playing a crucial role in soil fertility and sustainability, as it increases soil aggregate stability and water retention and provides a reservoir of essential nutrients for crops [200].

In addition, there is currently a growing interest in increasing the stock of SOC in agroecosystems because this can help mitigate climate change. In agricultural practices with high organic inputs, reduced or no tillage and permanent soil cover are capable of increasing SOC stock, acting as a carbon sink and thus mitigating the agricultural impacts on climate change [201,202]. On the other hand, the increase in SOC has positive effects on the quality of the soil, and this can improve the soil resilience, contributing to adaptation to climate change [203].

Soil tillage increases the decomposition rates of SOM, as it implies an alteration of the soil structure and the exposure of the organic matter retained in the micro-aggregates [204]. In a study by Repullo-Ruibérriz de Torres et al. [205], over a 4 year monitoring period on an olive plantation, SOM increased by the effect of different cover crops (*Brachypodium distachyon*, *Eruca vesicaria*, *Sinapis alba*, and native vegetation) between 10.9 and 14.3 Mg ha^{-1} at 0–40 cm soil depth.

The conversion of CT to conservation tillage increases the accumulation of SOC in the soil surface layer. CA increases SOC stock through the reduction in SOC losses by oxidation and erosion, the increase in organic carbon inputs to the soil (plant residues), or a combination of both factors [206,207]. Figure 5 summarizes conservation agriculture practices that may influence SOC stock increases.

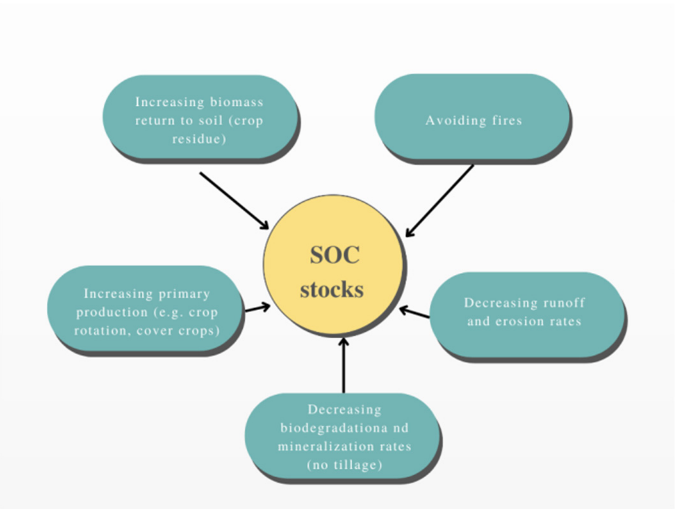

Figure 5. CA practices that increase SOC stock.

Changes in SOC storage with CA practices depend on various factors such as the quantity and quality of plant residues, time period, or edaphoclimatic characteristics [208]. These effects are most evident in the topsoil. In this context, the global analyses by Luo et al. [209] and Mondal et al. [210] indicated that a no-tillage system benefited the storage of SOC only in the upper 10 cm of the soil. Camarotto et al. [211] reported that CA increased the SOC stock in the 0–30 cm layer (0.25 Mg C ha^{-1} yr^{-1}) compared to conventional agriculture. In a maize–mustard rotation, Pooniya et al. [212] reported that CA systems had greater values for SOC than CT at soil depths of 0–0.15 m and 0.15–0.30 m, while at 0.30–0.45 m, there was no difference. Therefore, to obtain a more accurate assessment of CA practices' impact on SOC, the entire plow depth should be sampled [213]. In addition, comparing the results of experiments that compare CA with conventional systems is complicated, since they depend on several factors: depth of the investigated soil, sampling methodologies, duration of the study, edaphoclimatic variability, and crop type [211]. In irrigated almond orchards in Mediterranean semi-arid regions, according to Repullo-Ruibérriz de Torres [214], a crop mixture (65% barley and 35% vetch) and barley cover crops showed higher potential for C sequestration than spontaneous vegetation, augmenting the SOC by more than 1.0 Mg ha^{-1} after two monitoring seasons.

Long-term CA increased SOC content in the 0–5 cm soil layer in an intensive cereal-based cropping system in India [215]. In a study in northern Italy, Perego et al. [216] showed that CA systems in the medium term resulted in significantly higher SOC content and SOC stock than conventional systems. A study in rice (*Oryza sativa*)–wheat cropping systems in a South Asian region showed that the stratification and storage of SOC were higher under CA practices compared to intensive tillage-based conventional agricultural practices [217]. In a meta-analysis to evaluate the effects of minimum tillage and crop residue retention on SOC stock in 0–30 cm soil depths, Li et al. [218] reported that a no-tillage system with residue retention and a reduced tillage system with residue retention increased SOC stock by 13 and 12%, respectively, in comparison to CT. In a rice–wheat system, after 7 years, NT combined with partial residue retention increased SOC stock at 0.6 m depth [219].

4.2.2. Soil pH

The effect of conservation practices on soil pH is generally restricted to the topsoil layers. The effect of crop residues on soil pH depends on the chemical composition of the residues and the properties of the soil [220]. Residues high in ash alkalinity and N, such as some legume residues, will have a greater effect on pH compared to residues with lower content, such as wheat [221]. The initial pH of the soil has a substantial impact on the change in soil pH through the incorporation of crop residues, as it affects the mineralization of N in the residue and the rate of decomposition of organic compounds [222]. Similarly, a long-term study by Muchabi et al. [223] of fields under CA and CT highlighted a significantly higher soil pH (6.18 vs. 5.62), SOC, nodulation, and biological N fixation as a result of CA implementation after 7 years of practice. These findings are comparable with those reported earlier by Duiker and Beagle [224] and Umar et al. [225], who ascribed the upward changes in soil pH to the buffering effect of accumulated organic matter under CA. Recently, Sinha et al. [226] reported that the soil pH generally lowered under zero tillage compared to CT, being the most notable in acidic soil sites, where pH decreased by up to 0.4 units; the lower the initial soil pH, the higher was the decrease in pH under zero tillage.

Several studies have reported an increase in acidity in topsoil layers under reduced tillage treatments in comparison with CT [227,228]. This increase in acidity is attributed to a greater accumulation of soil organic matter on the soil surface in NT, which decomposes and produces acidity. In the deeper layers, there is an increase in pH because the soluble component of the residues moves through the soil profile and contributes to the alkalization of the subsoil layers [228,229]. In acid soils, various authors have reported that CA systems increased soil pH [229,230]. The organic matter that increases with CA practices tends to bring the pH to neutral or slightly acidic by buffering the pH of the soil. A long-term CA experiment carried out by Ligowe et al. [231] registered, on average, 14 and 21% higher pH and SOM, respectively, than the conventional practice, with a positive correlation (74%) between SOM and pH found during the fifth monitoring season.

4.2.3. Cation Exchange Capacity

The cation exchange capacity (CEC) is the ability of a soil to retain and release positive ions due to its content of clays and organic matter, and is considered an indicator of soil fertility. CA practices increase SOM content, and this provokes an increase in CEC [232], as it increases the amount of negative charges [233]. In this context, Ben Moussa-Machraoui et al. [234] reported a positive correlation between SOM and CEC. This increase in CEC driven by improvements in SOM via cover cropping can also lead to an increase in yield stability [235].

According to Sá et al. [233], CEC increased by 0.37 cmolc kg^{-1} for every gram of C per kg of soil. The effects on CEC are generally limited to the topsoil, which is where the SOM content is increased [224]. In this context, Williams et al. [235], in a study in the USA, showed that cover cropping increased SOM compared with no cover crop, implying a rise in CEC. In a tropical soil under no-till farming, CEC increased by 25% in the top soil layer (0–20 cm) with every 1.8 kg m^{-2} of stored organic carbon [236]. After 5 years, CEC increased in the topsoil when residues were retained compared to soils without residue [237]. Sithole and Magwaza [228], in a long-term study in South Africa, showed that CEC was affected by tillage practices. On average, CT resulted in a significantly lower (71.9 mmolc.kg^{-1}) CEC than rotational tillage (109 mmolc kg^{-1}) and NT (114 mmolc kg^{-1}). A long-term field experiment under rice-based cropping systems showed that the CEC was higher in NT than in CT, amounting to 13.04 and 9.76 cmol (p+) kg^{-1}, respectively [238]. In a tropical rainfed agroecosystem, the adoption of minimum tillage provoked an 11.2% increase in CEC compared with the CT system [239]. Moreover, Mloza-Banda et al. [93] reported a significant increase in CEC after 2 years of conversion to CA (15.24 cmol (+) kg^{-1}) compared to annual ridge tillage (13.38 cmol (+) kg^{-1}). Similarly, Zerihun et al. [240] reported an improvement in CEC with crop rotation and intercropping in CA systems.

Conversely, Fonteyne et al. [241], in a study in Mexico of 20 maize-based trials, did not register differences in CEC between CA and local conventional practices. Comparably, Mrabet et al. [242] did not find significant differences in CEC between CA and CT in a study in Morocco. The lack of difference between the different management systems may be due to the short duration of the studies or due to the influence of local soil conditions.

In other studies, a lower CEC was observed in soils under CA due to a decrease in pH, which resulted in a decrease in pH-dependent cation exchange sites [227,243].

4.2.4. Nutrient Availability

CA practices have a significant impact on nutrient distribution and transformation in soil; thus, they can strongly influence the soil nutrient dynamics [178]. That is, CA systems that cause an increase in organic matter due to the addition of residues can produce a rise in nutrient reserves for plants, registering higher concentrations of nitrogen (N) [244,245], phosphorus (P) [246,247], potassium (K) [228,247], calcium [248], magnesium [249], zinc [250], and manganese [249] in the soil. The nature of crop residues and their management has a significant influence on the plant nutrient availability of soils. For example, in the case of N, the addition of legume residues with a low C/N composition can result in N mineralization, whereas cereal residues with a high C/N composition can temporarily immobilize N during the decomposition process [251,252]. In a review study on the effects of crop residues under CA, Ranaivoson et al. [168] reported, in general, a higher increase in soil mineral N in the case of legume residues than in the case of cereal residues. The availability of nutrients with the retention of residues is also a function of other factors, such as the amount of surface residues or the proportion of soil covered by them [168]. The availability of nutrients in the soil can also be affected by the change in topsoil pH due to CA practices [253].

A greater amount of residues stored in the soil with CA systems does not always lead to a greater availability of nutrients for plants. Soon after CA is implemented, while total stores of N may be higher, the amount of plant-available N may decrease due to lower mineralization rates and higher N immobilization rates [111]; in this case, it is necessary to apply N fertilization to maintain the yield [228].

An NT system with a total absence of soil mixing can lead to the stratification of immobile nutrients such as P and K in the surface layers of soils [254]. In dry areas of Morocco, Mrabet et al. [242] showed that NT caused surface enrichment of P and K compared with CT. This can be a problem, especially in arid regions, as drought conditions can reduce nutrient uptake from the dry soil surface, inaccessible to plant roots [255]. Furthermore, these conditions can increase the risk of N and P losses by surface runoff [256]. Higher moisture content due to CA practices can lead to N losses due to denitrification [257]. Finally, according to Morugán et al. [258], the permanent cover crops in the alleys led to higher increases in SOC and soil N; however, this practice was related to negative effects on available P in the soil. Similarly, Sujatha et al. [259] claimed that the extensive root system of legumes was beneficial for improving their ability to release organic acids from their roots that enhanced K availability in soil. Table 3 shows the implantation effect of

CA practices compared to CT in hillslope farming with rainfed olive orchards in southeast Spain [260].

Table 3. Effect of CA practices on soil physico-chemical parameters in olive orchards throughout 3 year monitoring period (SE Spain).

Soil Management	Year	pH	MCP	BD	SOC	N_T	P	K	CEC
		(H_2O)	(%)	(g cm^{-3})	(g kg^{-1})		(mg kg^{-1})		(cmol (+) kg^{-1})
Minimum tillage and spontaneous vegetation strips	1st	7.5 (±0.1)	11.4 (±4.3)	1.17 (±0.04)	8.4 (±4.8)	0.45 (±0.03)	6.4 (±2.6)	68.7 (±18)	15.8 (±3.0)
	3rd	7.6 (±0.2)	12.6 (±3.6)	1.24 (±0.08)	10.2 (±7.5)	0.68 (0.05)	7.0 (±3.5)	77.7 (±26)	16.7 (±7.8)
Minimum tillage and legume strips	1st	7.5 (±0.2)	10.0 (±3.4)	1.18 (±0.14)	8.0 (±5.7)	0.58 (0.01)	4.6 (±1.7)	84.4 (±14)	10.2 (±4.4)
	3rd	7.7 (±0.5)	11.3 (±3.2)	1.26 (±0.07)	8.9 (±3.4)	0.67 (0.08)	5.2 (±4.2)	94.7 (±22)	14.7 (±7.1)
Conventional tillage	1st	7.5 (±0.1)	11.7 (±2.8)	1.20 (±0.09)	8.3 (±3.4)	0.55 (±0.03)	6.9 (±3.9)	67.5 (±18)	11.8 (±3.5)
	3rd	7.6 (±0.2)	10.1 (±3.1)	1.10 (±0.15)	7.2 (±2.7)	0.48 (±0.05)	7.2 (±2.7)	63.7 (±26)	12.7 (±7.4)

BD, bulk density; MCP, macroporosity; SOC, soil organic carbon; NT, total nitrogen; P, Olsen's extractable phosphorus; K, available potassium; CEC, cation exchange capacity. Values in parentheses are standard deviation.

According to Belay et al. [261], in supplementary irrigation vegetable production systems, CA practices can optimize nutrient use by decreasing nutrient losses through runoff and leaching. In this respect, several studies show that CA practices reduce the loss of nutrients via runoff or nutrients adsorbed in sediments lost by water erosion [176,262–265]. In this context, Jordan et al. [266] registered an 81% decrease in total P loss and a 94% decrease in organic nitrogen with non-inversion tillage compared with plow. In citrus orchards, the straw mulching covering the soil surface reduced runoff and sediment losses and subsequently decreased nutrient losses; the total nitrogen and phosphorus losses were significantly decreased by the straw mulching treatment compared with conventional treatments without mulching [267]. Liu et al. [268], using the Soil and Water Assessment Tool (SWAT), concluded that conservation tillage and contour farming can help reduce runoff by 15.99% and 9.16%, total nitrogen losses by 8.99% and 8%, and total phosphorus losses by 7% and 5%, respectively. In a study by García-Díaz et al. [269], the efficiency of using groundcover in vineyards to reduce mineral N losses via runoff was demonstrated.

As stated by Dinnes et al. [270], the strategies for reducing NO_3 loss through leaching can include CA practices by using cover crops, diversifying crop rotations, and reducing tillage. Cover crops or intercrops with deep-rooted plants reduce nutrient loss, intercepting leached nutrients from the root zone and returning them to the soil surface via mulch or as green manure. Wyland et al. [271] reported a 65–70% reduction in nitrate leaching from cover-cropped plots compared with the fallow control. In a study in Italy, CA practices had lower NO3 concentrations below the maximum rooting zone compared to conventional agricultural practices, thus reducing NO_3 leachate to groundwater [272]. According to Camarotto et al. [245], continuous soil cover and cover crops in CA systems reduced N leaching compared to conventional agriculture.

4.3. Influence on Soil Biological Properties

Soil biota plays a relevant role in soil health and sustainable crop production by supporting important functions such as soil aggregation, soil aeration, nutrient cycling, and bio-control, or the suppression of plant pathogens. Anthropogenic activities and especially intensive agriculture cause a considerable loss of soil biodiversity. Sustainable land uses are linked to the conservation of soil biological diversity [273]. Higher biodiversity means greater resilience to disturbances in the soil system [60]. The response of soil microorganisms and biochemical properties to soil management practices is measured by parameters such as the size and activity of the microbial community and soil enzymatic activities.

4.3.1. Microbial Activity

The soil microbial biomass (SMB) is commonly used to assess soil microbial activity, as this parameter responds quickly to changes in soil management. In this context, Zornoza et al. [274] stated that the quantitative description of the structure and diversity of the microbial community can be used as a tool for the evaluation of soil quality. That is, SMB can be used as an indicator of early changes in cropland management practices [275]. CA creates optimal conditions for microorganisms, with less frequent disturbance of the soil, increased SOM, improved water and thermal conditions, and increased diversity of substrates.

Crop diversification can increase soil microbial diversity and activities because the roots of cover crops release exudates in intercropping systems, contributing to greater microbial biomass [276]. In this context, Lopes and Fernandes [277] registered an increase in microbial biomass C with intercropping compared with monoculture. Singh et al. [278] reported that CA management systems can lead to an improvement in soil biota. Similarly, Wang et al. [279], in a study in drylands of northern China, reported a more diverse soil bacterial community in conservation tillage soils than in CT soils. Moreover, Silva et al. [280] registered a decrease in microbial diversity as tillage practices intensified. Dorr de Cuadros et al. [281] showed that microbial diversity was significantly higher in the NT system at four taxonomic levels (order, family, genus, and species) compared with the CT system. Henneron et al. [282] analyzed the long-term effects of CA on soil biodiversity, finding an improvement in the biomass and biodiversity of microorganisms. Baghel et al. [283], in a rice–wheat cropping system, recorded higher microbial biomass carbon under CA practices compared to CT. In a maize–mustard rotation, the zero-tilled flatbed and permanent bed CA practices improved soil biological properties, with higher SMB-C than CT [212].

Additionally, in a meta-analysis of 96 paired experiments, Li et al. [284] showed that CA practices (NT with residue retention) resulted in higher soil microbial biomass carbon (SMB-C) and nitrogen (SMB-N), and microbial quotient (qMic, Cmic-to-organic C ratio). In a continuous rice–wheat rotation, zero tillage and residue cycling compared to CT and residue removal increased SMB-C by 29 and 56%, respectively, whereas the SMB-N increased by 27 and 84%, respectively [285]. In a pigeon pea (*Cajanus cajan* (L.) Millsp.) and soybean intercropping system, conservation tillage systems recorded significantly higher SMB-C and SMB-N levels than CT without crop residues [286]. Spedding et al. [287] reported higher SMB-C and N levels in plots with residue retention than with residue removal, although the differences were significant only in the 0–10 cm layer. This agrees with Ceja-Navaro et al. [288], who found that in soils under NT with a monoculture of maize and removal of crop residue, microbial diversity was strongly reduced compared to soil under wheat NT where crop residues were retained. According to Legrand et al. [289], soil tillage is the agronomic practice that most influences soil bacterial diversity, with a greater functional and taxonomic diversity of bacteria in agricultural soils with minimal tillage compared to conventional tillage. In this context, Mathew et al. [290] reported a higher microbial biomass at the 0–5 cm depth in a long-term no-tillage system than in a conventional tillage system. According to Lopes and Fernandes [277], the changes in microbial community composition do not coincide with the increased soil physical quality resulting from CA practices, indicating the influence of other factors, such as edaphic or anthropic, on the soil microbial profile.

The crop system also influences microbial diversity. In this respect, Dorr de Cuadros et al. [281] reported greater microbial diversity in soils with a crop system based on cereals without legumes. That is, cereal straw substrates have a higher C:N ratio, which stimulates the microbial community to degrade organic substrate and leads to an increase in the microbial population.

4.3.2. Soil Enzymatic Activities

The microbial enzymatic activities of the soil serve as an indicator of the potential of the soil to decompose organic C and mineralize nutrients (P and N), and thereby nutrients available for plants. Soil enzymatic functions are greatly influenced by the cropping system and the degree of soil disturbance [291].

The main enzymes used to determine soil health are β-glucosidase, N-acetyl-glucosaminidase, and acid phosphatase, which are responsible for mediating C, N, and P cycling in the soil, respectively. According to Bonini-Pires et al. [292], the association of NT and increased crop rotation enhanced enzymatic activity in the soil surface. In a rice–wheat system in India, soil enzyme activities increased (5–18%) under an NT system with residues compared to an NT system without residues and a CT system without residues [293]. The implementation of CA in maize rotations improved soil enzymatic activities [104]. Similarly, Kumar and Babalad [286] registered significantly higher soil urease, dehydrogenase, and total phosphate activities in conservation tillage systems as compared to CT without crop residue. According to Choudhary et al. [285], soil enzyme activities were significantly increased in a conservation agriculture-based maize–wheat system.

In a study by Sharma et al. [294], an NT rice–wheat system with rice residue mulch increased soil dehydrogenase, cellulase, and alkaline phosphatase activities by 23%, 34%, and 14%, respectively, compared to CT. Pooniya et al. [212] reported that CA practices (zero-tilled flatbed and permanent bed) significantly increased dehydrogenase, alkaline phosphatase, and urease activities compared with CT.

The impact of CA practices on soil microbial and enzymatic activities in hillslope farming with rainfed olive orchards compared to CT is shown in Table 4 [259]. Moreover, Kandeler et al. [295] determined that protease and phosphatase activities significantly increased after only 2 years of minimum tillage compared to CT. Similarly, Roldán et al. [296] found that CA techniques based on zero tillage and legume cover remarkably enhanced the soil enzyme activities (dehydrogenase, urease, protease, β-glucosidase, and acid phosphatase). In a study by Pandey et al. [297], the no-till system fostered an improvement in the activities of β-glucosidase as well as microbial biomass carbon and nitrogen compared to CT. Similarly, Sinsabaugh et al. [298] found that minimum tillage promotes β-glucosidase activity due to the augmentation in microbial biomass, more substrate availability, and reduced soil disturbance, as was noted in a CA system compared to CT.

Table 4. Effect of CA practices on soil microbial and enzymatic activities in olive orchards throughout 3 year monitoring period (SE Spain).

Soil Management	Year	MB_N	MB_C	B-GLU	PRO	DHA	PHP
		(mg kg^{-1})		(μg pNP g^{-1} h^{-1})	(μg TRS g^{-1} h^{-1})	(μg TPF g^{-1} h^{-1})	(μg pNP g^{-1} h^{-1})
Minimum tillage and spontaneous vegetation strips	1st	5.8 (±2.2)	3.4 (±1.4)	401 (±1.2)	12.0 (±1.4)	99.20 (±1.9)	131.5 (±11.8)
	3rd	6.9 (±3.4)	3.8 (±1.1)	452 (±2.4)	12.8 (±1.5)	111.8 (±3.4)	139.8 (±22.4)
Minimum tillage and legume strips	1st	5.0 (±1.2)	3.1 (±1.0)	461 (1.9)	11.9 (±0.9)	100.7 (±2.7)	120.4 (±17.1)
	3rd	6.4 (±0.9)	4.2 (±2.4)	483 (±3.5)	12.7 (±1.6)	119.1 (±5.2)	131.4 (±13.7)
Conventional tillage	1st	5.3 (±0.8)	2.0 (±0.8)	131 (±1.2)	11.7 (±1.4)	92.43 (±5.1)	122.0 (±21.5)
	3rd	4.3 (±0.7)	1.3 (±0.9)	196 (±1.8)	12.4 (±1.9)	92.78 (±4.9)	129.6 (±20.9)

β-GLU, β-glucosidase; PRO, protease; DHA, Dehydrogenase; PHP, Phosphatase; MBN, microbial biomass-nitrogen; MBC, microbial biomass-carbon. Values in parentheses are standard deviation.

Ultimately, it is evident that CA practices positively impact soil microorganisms and microbial processes ascribed to changes in the quantity and quality of plant residues that enter the soil, their spatial distribution, changes in the provision of nutrients, and physical alterations. Consequently, the alternative modifications to CT systems, especially those based on methods used in CA, are able to boost important functions for soil health restoration.

4.3.3. Earthworms

Earthworms are one of the most important soil macrofaunal groups and are described as ecosystem engineers because of their effects on soil properties and on the availability of resources for other organisms [299]. They determine the nutrient cycle, microbial activity, the stability of soil aggregates, and the density and distribution of other invertebrates. Soil tillage causes physical damage to earthworms as well as alterations of their habitat, and can vary the community structure and relative abundance of earthworms [300]. The variability in burrowing and feeding behaviors influences the effects that tillage type can have on earthworms [301]. Thus, the species that inhabit the topsoil are most at risk of being adversely affected by plowing [302]. Earthworms have been observed to respond positively to CA practices. Contrarily, a study by Baldivieso-Freitas et al. [303] did not register any positive effects of the combination of CA techniques (reduced tillage by chiseling and green manures) on earthworm populations in a Mediterranean environment. However, organic fertilization showed a more significant role and enhanced their population. Therefore, it is crucial to understand how different factors (soil properties, crop rotations, and climate conditions) interact when designing a sustainable organic system.

According to Van Capelle et al. [304], the increase in earthworm density under no-till systems is due to the interactions of different effects: reduced injuries, decreased exposure to predators at the soil surface, reduced microclimate changes, and increased availability of organic matter. Radford et al. [305] reported that earthworm numbers increased fourfold with a zero-tillage system as compared to CT. Birkás et al. [306], in a study in Hungary, registered significantly more earthworms in soils under a conservation tillage system that included leaving stubble residues on the surface, compared to soils that were deteriorated by tillage pans and left bare without residues. In a study in Zambia, soils under CA practices with residue retention and crop rotation had higher earthworm populations in the top 30 cm than soils under conventionally ploughed practices [87]. Errouissi et al. [307] showed that zero tillage with surface residue increased the populations and diversity of soil invertebrates, including earthworms, compared to CT because of improved soil properties and a lack of soil disturbance. Crop residues retained on the soil surface and minimum soil disturbance improve soil structure, are a food resource, and cool the soil temperature, allowing the number and biomass of earthworms to increase [308]. In a study in central Mexico, Castellanos-Navarrete et al. [84] showed that CA produced an evident increase in the abundance and biomass of earthworms compared to CT. Sharma and Dhaliwal [309], in a study of rice–wheat cropping systems in South Asia, concluded that a zero-tillage system with crop residue retention improved micronutrient contents and provided feeding for soil macrofauna, especially earthworms, as compared to conventional tillage without residue. In a long-term trial in Zambia, Muoni et al. [310] concluded that reduced tillage systems and crop rotations increase biological activity, with the density of termites and earthworms being higher in CA systems than in CT systems. Henneron et al. [282] reported an increase in anecic earthworms in the long term in CA systems. Additionally, Pelosi et al. [302] reported that the decrease in soil tillage intensity led to an increase in functional diversity and an increase in the density of anecic earthworms. Several studies have reported a positive impact of management systems that include diversified crop rotations on earthworm density [311,312].

4.3.4. Soil Respiration

Soil respiration comprises the oxidation of organic matter by microorganisms and rhizosphere respiration [313]. It is a measure of the metabolic activity of the soil microbial community and is considered as the second-largest terrestrial carbon flux worldwide [314]. It is one of the most widely used soil biological indicators in soil quality evaluations [62].

Soil respiration is sensitive to soil disturbances, so it can be used as an indicator to detect soil degradation early [315].

Soil management affects the soil microclimate and biotic factors (soil organic carbon, aboveground biomass, root biomass, and plant residues) that indirectly influence soil respiration [316]. Several studies have reported the effect of conservation agriculture practices on soil microbial respiration [277,317,318], without consistent trends. Some studies did not report significant differences in soil respiration between conventional tillage and conservation agriculture practices [277,319,320]. This may be because tillage seems to affect the temporal distribution more than the total amount of CO_2 emissions from the soil [321]. Therefore, to achieve an accurate assessment of the effects of agricultural practices on soil respiration, it is necessary to design a seasonal sampling [322]. In contrast, other studies recorded significantly higher soil respiration values in CA systems than in CT systems. In a study in Cambodia, Edralin et al. [317] reported higher soil respiration in CA (55.9 ± 4.8 kg CO_2-C ha^{-1} day^{-1}) than in CT (36.2 ± 13.5 kg CO_2-C ha^{-1} day^{-1}). In the long term, NT increased soil respiration compared to CT, by 16, 19 and 26% after 6, 20 and 35 years of implantation [103]. Additionally, a 12 year study showed that, compared to conventional tillage, no-till practices resulted in higher soil microbial respiration [323]. Sapkota et al. [103] reported higher soil respiration in no-tillage systems than in conventional tillage (+44%). In an apricot orchard, cover crops increased soil respiration compared to plots with bare control, herbicide control or mechanical cultivation [324].

According to Williams et al. [325], agricultural practices that imply the greater crop diversity, reduction in mechanical soil disturbance and/or an increase in organic amendment inputs that characterize CA systems improve the microbiological activity of the soil. CA practices increase organic carbon inputs to the soil, for example, through plant residues, improving soil biological activity [326]. In this context, Bera et al. [327] observed a significant and high positive correlation between SOC and basal soil respiration, of 0.84.

5. Conclusions and Future Perspectives

The main challenge of conserving and improving soil health is guaranteeing its long-term productivity and environmental sustainability. As was reviewed, CA systems can be implemented to minimize negative socioeconomic and environmental consequences associated with soil degradation by enhancing soil health and promoting the sustainability and multifunctionality of agroecosystems.

To meet the global challenges of food security and environmental conservation, CA has been identified as one of the technological options for a sustainable intensification of agriculture. CA systems have clear advantages over conventional agricultural systems in improving soil health and the efficient use of natural resources, reducing the environmental impacts of agricultural activities, saving inputs, reducing the cost of production, etc.

Regarding the implementation of CA practices, there are a number of restrictions and challenges that must be addressed in order to increase their adoption on a large scale:

- Unavailability of appropriate equipment and machines, especially for small- and medium-scale farms;
- Use of crop residues for livestock feed and fuel;
- Lack of knowledge about the benefits of CA and how to implement CA;
- Farmer mind-sets that limit the adoption of CA due to traditions or prejudices;
- Lack of technical and financial support from governments, international organizations, and/or extension agencies;
- Technical problems that can arise with the adoption of CA practices such as inadequate weed management, nutrient stratification, lower N availability, development of surface crust, etc., which can translate into a decrease in yield and can motivate farmers to abandon the system.

To overcome these constraints and increase the performance of CA worldwide, it is essential that CA systems be well-adapted to specific agronomic, environmental, social, and economic conditions. Consequently, it is necessary to carry out the following measures, among others:

- Improve the availability of machinery and supplies of plant nutrition;
- Identify and eliminate sociocultural barriers to CA adoption;
- Improve locally adapted management, such as appropriate crop rotations or the frequency and optimal timing of strategic tillage;
- Increase institutional support, research, efficiency of extension services, and information dissemination mechanisms.

Finally, in order to guarantee the long-term productivity and environmental sustainability of agroecosystems, it will be vital to develop new tools and methodologies to assess soil quality and health that can be used to evaluate and guide soil management decisions.

Author Contributions: Conceptualization, B.C.R. and V.H.D.-Z.; writing—review and editing, B.C.R., V.H.D.-Z., M.S.R., I.F.G.-T., B.G.R. and S.C.T. All authors have read and agreed to the published version of the manuscript.

Funding: The first author, Belén Cárceles Rodríguez, has a contract co-financed by the National Institute for Agricultural and Food Research and Technology (FPI-INIA 2018) and the European Social Fund (ESF), "The European Social Fund invests in your future". This publication was sponsored by the following research projects: "Integrated soil and water management in rainfed almond in a context of sustainable agriculture" (RTA2017-00097-00-00) granted by the INIA (National Institute for Agricultural and Food Research and Technology) and the MINECO (Spanish Ministry of Economy and Competitiveness), and partially by the project "Sustainable intensification of almond (Prunus dulcis Mill.) cultivation in a context of climate change (ISACLIMA)" (SG1.SG12020.005, PY20_00999).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

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

References

1. Foley, J.; Ramankutty, N.; Brauman, K.; Cassidy, E.S.; Gerber, J.S.; Johnston, M.; Mueller, N.D.; O'Connell, C.; Ray, D.K.; West, P.C.; et al. Solutions for a cultivated planet. *Nature* **2011**, *478*, 337–342. [CrossRef] [PubMed]
2. German, R.N.; Thompson, C.E.; Benton, T.G. Relationships among multiple aspects of agriculture's environmental impact and productivity: A meta-analysis to guide sustainable agriculture. *Biol. Rev. Camb. Philos. Soc.* **2017**, *92*, 716–738. [CrossRef] [PubMed]
3. Shah, F.; Wu, W. Soil and Crop Management strategies to ensure higher crop productivity within sustainable environments. *Sustainability* **2019**, *11*, 1485. [CrossRef]
4. Tahat, M.M.; Alananbeh, K.M.; Othman, Y.A.; Leskovar, D.I. Soil health and sustainable agriculture. *Sustainability* **2020**, *12*, 4859. [CrossRef]
5. Kibblewhite, M.G.; Ritz, K.; Swift, M.J. Soil health in agricultural systems. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **2008**, *363*, 685–701. [CrossRef] [PubMed]
6. FAO & ITPS. *Status of the World's Soil Resources (SWSR): Main Report*; Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils: Rome, Italy, 2015; Volume 650. Available online: https://www.fao.org/3/i5199e/i5199e.pdf (accessed on 9 November 2021).
7. Moebius-Clune, B.N.; Moebius-Clune, D.J.; Gugino, B.K.; Idowu, O.J.; Schindelbeck, R.R.; Ristow, A.J.; van Es, H.M.; Thies, J.E.; Shayler, H.A.; McBride, M.B.; et al. *Comprehensive Assessment of Soil Health—The Cornell Framework, 3.2 ed.*; Cornell University: Geneva, NY, USA, 2016.
8. Smith, P.; Gregory, P.J. Climate change and sustainable food production. *Proc. Nutr. Soc.* **2013**, *72*, 21–28. [CrossRef] [PubMed]
9. Choudary, M.; Ghasal, P.C.; Kumar, S.R.P.; Yadav, S.S.; Meena, V.S.; Bisht, J.K. Conservation Agriculture and Climate Change: An Overview. In *Conservation Agriculture*; Bisht, J., Meena, V., Mishra, P., Pattanayak, A., Eds.; Springer: Singapore, 2020. [CrossRef]
10. González-Sánchez, E.J.; Moreno-García, M.; Kassam, A.; Holgado-Cabrera, A.; Triviño-Tarradas, P.; Carbonell-Bojollo, R.; Pisante, M.; Veroz-González, O.; Basch, G. *Conservation Agriculture: Making Climate Change Mitigation and Adaptation Real in Europe*; ECAF: Brussels, Belgium, 2017. [CrossRef]
11. Smith, P.; Olesen, J.E. Synergies between the mitigation of, and adaptation to, climate change in agriculture. *J. Agric. Sci* **2010**, *148*, 543–552. [CrossRef]

12. Lobell, D.B.; Burke, M.B.; Tebaldi, C.; Mastrandrea, M.D.; Falcon, W.P.; Naylor, R.L. Prioritizing climate change adaptation needs for food security in 2030. *Science* **2008**, *319*, 607–610. [CrossRef] [PubMed]
13. Palm, C.; Blanco-Canqui, H.; DeClerck, F.; Gatere, L.; Grace, P. Conservation agriculture and ecosystem services: An overview. *Agric. Ecosyst. Environ.* **2014**, *187*, 87–105. [CrossRef]
14. Doran, J.W.; Zeiss, M.R. Soil health and sustainability: Managing the biotic component of soil quality. *Appl. Soil Ecol.* **2000**, *15*, 3–11. [CrossRef]
15. Pérez-Escamilla, R. Food Security and the 2015–2030 Sustainable Development Goals: From Human to Planetary Health: Perspectives and Opinions. *Curr. Dev. Nutr.* **2017**, *1*, e000513. [CrossRef] [PubMed]
16. Shrestha, J.; Subedi, S.; Timsina, K.; Chaudhary, A.; Kandel, M.; Tripathi, S. Conservation agriculture as an approach towards sustainable crop production: A Review. *Farming Manag.* **2020**, *5*, 7–15. [CrossRef]
17. Holland, J.M. The environmental consequences of adopting conservation tillage in Europe: Reviewing the evidence. *Agric. Ecosyst. Environ.* **2004**, *103*, 1–25. [CrossRef]
18. FAO. Conservation Agriculture. 2015. Available online: https://www.fao.org/conservation-agriculture/en/ (accessed on 19 October 2021).
19. Ikazaki, K.; Nagumo, F.; Simporé, S.; Barro, A. Are all three components of conservation agriculture necessary for soil conservation in the Sudan Savanna? *Soil Sci. Plant Nutr.* **2018**, *64*, 230–237. [CrossRef]
20. Jat, M.L.; Chakraborty, D.; Ladha, J.K.; Rana, D.S.; Gathala, M.K.; McDonald, A.; Gerard, B. Conservation agriculture for sustainable intensification in South Asia. *Nat. Sustain.* **2020**, *3*, 336–343. [CrossRef]
21. Yigezu, Y.A.; El-Shater, T.; Boughlala, M.; Devkota, M.; Mrabet, R.; Moussadek, R. Can an incremental approach be a better option in the dissemination of conservation agriculture? Some socioeconomic justifications from the drylands of Morocco. *Soil Tillage Res.* **2021**, *212*, 105067. [CrossRef]
22. Giller, K.E.; Andersson, J.A.; Corbeels, M.; Kirkegaard, J.; Mortensen, D.; Erenstein, O.; Vanlauwe, B. Beyond conservation agriculture. *Front. Plant Sci.* **2015**, *6*, 870. [CrossRef]
23. Rodenburg, J.; Büchi, L.; Haggar, J. Adoption by adaptation: Moving from Conservation Agriculture to conservation practices. *Int. J. Agric. Sustain.* **2020**, *19*, 437–455. [CrossRef]
24. FAO. *Save and Grow: A Policymaker's Guide to the Sustainable Intensification of Smallholder Crop Production*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2011. Available online: https://www.fao.org/3/i2215e/i2215e.pdf (accessed on 16 November 2021).
25. Das, T.K.; Nath, C.P.; Das, S.; Biswas, S.; Bhattacharyya, R.; Sudhishri, S.; Raj, R.; Singh, B.; Kakralia, S.K.; Rathi, N.; et al. Conservation agriculture in rice-mustard cropping system for five years: Impacts on crop productivity, profitability, water-use efficiency, and soil properties. *Field Crops Res.* **2020**, *250*, 107781. [CrossRef]
26. Jat, H.S.; Choudhary, K.M.; Nandal, D.P.; Yadav, A.K.; Poonia, T.; Singh, Y.; Sharma, P.C.; Jat, M.L. Conservation agriculture-based sustainable intensification of cereal systems leads to energy conservation, higher productivity and farm profitability. *Environ. Manag.* **2020**, *65*, 774–786. [CrossRef]
27. Kassam, A.; Friedrich, T.; Derpsch, R. Global spread of Conservation Agriculture. *Int. J. Environ. Stud.* **2019**, *76*, 29–51. [CrossRef]
28. Derpsch, R.; Friedrich, T.; Kassam, A.; Li, H. Current status of adoption of no-till farming in the world and some of its main benefits. *Int. J. Agric. Biol. Eng.* **2010**, *3*, 1–25. [CrossRef]
29. Lal, R. Sustainable intensification of China's agroecosystems by conservation agriculture. *Int. Soil Water Conserv. Res.* **2018**, *6*, 1–12. [CrossRef]
30. Bhan, S.; Behera, U.K. Conservation agriculture in India—Problems, prospects and policy issues. *Int. Soil Water Conserv. Res.* **2014**, *2*, 1–12. [CrossRef]
31. Hobbs, P.R. Conservation agriculture: What is it and why is it important for future sustainable food production? *J. Agric. Sci.* **2007**, *145*, 127–137. [CrossRef]
32. Sahu, G.; Mohanty, S.; Das, S. Conservation agriculture—A way to improve soil health. *J. Exp. Biol. Agric. Sci.* **2020**, *8*, 355–368. [CrossRef]
33. Gonzalez-Sanchez, E.J.; Veroz, G.O.; Moreno, G.M.; Gomez, A.M.R.; Ordoñez, F.R.; Trivino, T.P.; Kassam, A.; Gil, R.J.A.; Basch, G.; Carbonell, B.R. Climate change adaptability and mitigation with conservation agriculture. In *Food Science, Technology and Nutrition, Rethinking Food and Agriculture*; Woodhead Publishing Series; Kassam, A., Kassam, L., Eds.; Woodhead Publishing: Sawston, UK, 2021; pp. 231–246. [CrossRef]
34. Indoria, A.K.; Rao, C.S.; Sharma, K.L.; Reddy, K.S. Conservation agriculture—A panacea to improve soil physical health. *Curr. Sci.* **2017**, *112*, 52–61. Available online: http://www.jstor.org/stable/24911616 (accessed on 10 November 2022). [CrossRef]
35. Subbulakshmi, S.; Saravanan, N.; Subbian, P. Conventional tillage vs. conservation tillage—A review. *Agric. Rev.* **2009**, *30*, 56–63.
36. Madarász, B.; Juhos, K.; Ruszkiczay, R.Z.; Benke, S.; Jakab, G.; Szalai, Z. Conservation tillage vs. conventional tillage: Long-term effects on yields in continental, sub-humid Central Europe, Hungary. *Int. J. Agric. Sustain.* **2016**, *14*, 408–427. [CrossRef]
37. Jacobs, A.; Helfrich, M.; Hanisch, S.; Quendt, U.; Rauber, R.; Ludwig, B. Effect of conventional and minimum tillage on physical and biochemical stabilization of soil organic matter. *Biol. Fertil. Soils* **2010**, *46*, 671–680. [CrossRef]
38. Busari, A.M.; Kuka, L.S.S.; Amanpreet, K.; Bhatt, R.; Dulazi, A.A. Conservation tillage impacts on soil, crop and the environment. *Int. Soil Water Conserv. Res.* **2015**, *2*, 119–129. [CrossRef]
39. Stevens, A.W. Review: The economics of soil health. *Food Policy* **2018**, *80*, 1–9. [CrossRef]

40. White, C.M.; DuPont, S.T.; Hautau, M.; Hartman, D.; Finney, D.M.; Bradley, B.; LaChance, J.C.; Kaye, J.P. Managing the trade-off between nitrogen supply and retention with cover crop mixtures. *Agric. Ecosyst. Environ.* **2017**, *237*, 121–133. [CrossRef]
41. Schipanski, M.E.; Barbercheck, M.; Douglas, M.R.; Finney, D.M.; Haider, K.; Kaye, J.P.; Kemanian, A.R.; Mortensen, D.A.; Ryan, M.R.; Tooker, J.; et al. A framework for evaluating ecosystem services provided by cover crops in agroecosystems. *Agric. Syst.* **2014**, *125*, 12–22. [CrossRef]
42. Jaffuel, G.; Blanco-Pérez, R.; Büchi, L.; Mäder, P.; Fließbach, A.; Charles, R.; Degen, T.; Turlings, T.C.J.; Campos-Herrera, R. Effects of cover crops on the overwintering success of entomopathogenic nematodes and their antagonists. *Appl. Soil Ecol.* **2017**, *114*, 62–73. [CrossRef]
43. Lyon, D.J.; Nielsen, D.C.; Felter, D.G.; Burgener, P.A. Choice of summer fallow replacement crops impacts subsequent winter wheat. *Agron. J.* **2007**, *99*, 578–584. [CrossRef]
44. Kaspar, T.C.; Jaynes, D.B.; Parkin, T.B.; Moorman, T.B.; Singer, J.W. Effectiveness of oat and rye cover crops in reducing nitrate losses in drainage water. *Agric. Water Manag.* **2012**, *110*, 25–33. [CrossRef]
45. 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]
46. Cates, A.M.; Ruark, M.D.; Grandy, A.S.; Jackson, R.D. Small soil C cycle responses to three years of cover crops in maize cropping systems. *Agric. Ecosyst. Environ.* **2019**, *286*, 106649. [CrossRef]
47. Abdalla, M.; Hastings, A.; Cheng, K.; 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]
48. Minasny, B.; Malone, B.P.; McBratney, A.B.; Angers, D.A.; Arrouays, D.; Chambers, A.; Chaplot, V.; Chen, Z.S.; Cheng, K.; Das, B.S.; et al. Soil carbon 4 per mille. *Geoderma* **2017**, *292*, 59–86. [CrossRef]
49. García-Tejero, I.F.; Carbonell, B.R.; Ordoñez, F.R.; Torres, F.P.; Durán, Z.V.H. Conservation agriculture practices to improve the soil water management and soil carbon storage in Mediterranean rainfed agro-ecosystems. In *Soil Health Restoration and Management*; Meena, R., Ed.; Springer: Singapore, 2020; pp. 203–230. [CrossRef]
50. Daryanto, S.; Fu, B.; Wang, L.; Jacinthe, P.A.; Zhao, W. Quantitative synthesis on the ecosystem services of cover crops. *Earth-Sci. Rev.* **2018**, *185*, 357–373. [CrossRef]
51. Clark, A.J.; Decker, A.M.; Meisinger, J.J.; McIntosh, M.S. Kill date of vetch, rye, and a vetch-rye mixture: I. Cover crop and corn nitrogen. *Agron. J.* **1997**, *89*, 427–434. [CrossRef]
52. Ladan, S.; Jacinthe, P.A. Nitrogen availability and early corn growth on plowed and no till soils amended with different types of cover crops. *J. Soil Sci. Plant Nutr.* **2017**, *1*, 74–90. [CrossRef]
53. Mitchell, J.P.; Shrestha, A.; Irmak, S. Trade-offs between winter cover crop production and soil water depletion in the San Joaquin Valley, California. *J. Soil Water Conserv.* **2015**, *70*, 430–440. [CrossRef]
54. Stagnari, F.; Galieni, A.; Speca, S.; Cafiero, G.; Pisante, M. Effects of straw mulch on growth and yield of durum wheat during transition to conservation agriculture in Mediterranean environment. *Field Crops Res.* **2014**, *167*, 51–63. [CrossRef]
55. Bhullar, M.S.; Pandey, M.; Kumar, S.; Gill, G. Weed management in conservation agriculture in India. *Indian J. Weed Sci.* **2016**, *48*, 1–12. [CrossRef]
56. Farooq, M.; Flower, K.C.; Jabran, K.; Wahid, A.; Siddique, K.H.M. Crop yield and weed management in rainfed conservation agriculture. *Soil Tillage Res.* **2011**, *117*, 172–183. [CrossRef]
57. Bonfante, A.; Basile, A.; Bouma, J. Targeting the soil quality and soil health concepts when aiming for the United Nations Sustainable Development Goals and the EU Green Deal. *Soil* **2020**, *6*, 453–466. [CrossRef]
58. Laishram, J.; Saxena, K.G.; Maikhuri, R.K.; Rao, K.S. Soil quality and soil health: A review. *Int. J. Ecol. Environ. Sci.* **2012**, *38*, 19–37.
59. USDA. Available online: https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/ (accessed on 25 October 2021).
60. Yang, T.; Siddique, K.H.M.; Liu, K. Cropping systems in agriculture and their impact on soil health—A review. *Glob. Ecol. Conserv.* **2020**, *23*, e01118. [CrossRef]
61. Wang, K.H.; Hooks, C.R.R. Chapter 4: Managing soil health and soil health bioindicators through the use of cover crops and other sustainable practices. In *MD Organic Vegetable Growers*; Brust, G.E., Ed.; University of Maryland: College Park, MD, USA, 2011.
62. Bünemann, E.K.; Bongiorno, G.; Bai, Z.; Creamer, R.E.; De Deyn, G.; de Goede, R.; Fleskens, L.; Geissen, V.; Kuyper, T.W.; Mäder, P.; et al. Soil quality—A critical review. *Soil Biol. Biochem.* **2018**, *120*, 105–125. [CrossRef]
63. Fierer, N.; Wood, S.A.; Bueno de Mesquita, C.P. How microbes can, and cannot, be used to assess soil health. *Soil Biol. Biochem.* **2021**, *153*, 108111. [CrossRef]
64. Thoumazeau, A.; Bessou, C.; Renevier, M.S.; Trap, J.; Marichal, R.; Mareschal, L.; Decaëns, T.; Bottinelli, N.; Jaillard, B.; Chevallier, T.; et al. Biofunctool®: A new framework to assess the impact of land management on soil quality: Part A: Concept and validation of the set of indicators. *Ecol. Indic.* **2019**, *97*, 100–110. [CrossRef]
65. Mukherjee, A.; Lal, R. Comparison of soil quality index using three methods. *PLoS ONE* **2014**, *9*, e105981. [CrossRef] [PubMed]
66. Cherubin, M.R.; Karlen, D.L.; Cerri, C.E.P.; Franco, A.L.C.; Tormena, C.A.; Davies, C.A.; Cerri, C.C. Soil quality indexing strategies for evaluating sugarcane expansion in Brazil. *PLoS ONE* **2016**, *11*, e0150860. [CrossRef]
67. Lehmann, J.; Bossio, D.A.; Kögel-Knabner, I.; Rillig, M.C. The concept and future prospects of soil health. *Nat. Rev. Earth Environ.* **2020**, *1*, 544–553. [CrossRef]

68. Rinot, O.; Levy, G.J.; Steinberger, Y.; Svoray, T.; Eshel, G. Soil health assessment: A critical review of current methodologies and a proposed new approach. *Sci. Total Environ.* **2019**, *648*, 1484–1491. [CrossRef]
69. Cardoso, E.J.B.N.; Vasconcellos, R.L.F.; Bini, D.; Miyauchi, M.Y.H.; dos Santos, C.A.; Alves, P.R.L.; de Paula, A.M.; Nakatani, A.S.; Pereira, J.M.; Nogueira, M.A. Soil health: Looking for suitable indicators: What should be considered to assess the effects of use and management on soil health? *Sci. Agric.* **2013**, *70*, 274–289. [CrossRef]
70. Hermans, T.D.G.; Dougill, A.J.; Whitfield, S.; Peacock, C.L.; Eze, S.; Thierfelder, C. Combining local knowledge and soil science for integrated soil health assessments in conservation agriculture systems. *J. Environ. Manag.* **2021**, *286*, 112192. [CrossRef]
71. Andrews, S.S.; Karlen, D.L.; Mitchell, J.P. A comparison of soil quality indexing methods for vegetable production systems in Northern California. *Agric. Ecosyst. Environ.* **2002**, *90*, 25–45. [CrossRef]
72. Morrow, J.G.; Huggins, D.R.; Carpenter-Boggs, L.A.; Reganold, J.P. Evaluating measures to assess soil health in long-term agroecosystem trials. *Soil Sci. Soc. Am. J.* **2016**, *80*, 450–462. [CrossRef]
73. Qi, Y.; Darilek, J.L.; Huang, B.; Zhao, Y.; Sun, W.; Gu, Z. Evaluating soil quality indices in an agricultural region of Jiangsu Province, China. *Geoderma* **2009**, *149*, 325–334. [CrossRef]
74. Caron, P.; Biénabe, E.; Hainzelin, E. Making transition towards ecological intensification of agriculture a reality: The gaps in and the role of scientific knowledge. *Curr. Opin. Environ. Sustain.* **2014**, *8*, 44–52. [CrossRef]
75. Kassam, A.; Derpsch, R.; Friedrich, T. Global achievements in soil and water conservation: The case of conservation agriculture. *Int. Soil Water Conserv. Res.* **2014**, *2*, 5–13. [CrossRef]
76. Bronick, C.J.; Lal, R. Soil structure and management: A review. *Geoderma* **2005**, *124*, 3–22. [CrossRef]
77. Liu, M.; Han, G.; Zhang, Q. Effects of Soil Aggregate Stability on Soil Organic Carbon and Nitrogen under Land Use Change in an Erodible Region in Southwest China. *Int. J. Environ. Res. Public Health* **2019**, *16*, 3809. [CrossRef] [PubMed]
78. Spohn, M.; Giani, L. Impacts of land use change on soil aggregation and aggregate stabilizing compounds as dependent on time. *Soil Biol. Biochem.* **2011**, *43*, 1081–1088. [CrossRef]
79. Six, J.; Bossuyt, H.; Degryze, S.; Denef, K. A history of research on the link between (micro) aggregates, soil biota, and soil organic matter dynamics. *Soil Tillage Res.* **2004**, *79*, 7–31. [CrossRef]
80. Cherubin, M.R.; da Silva Oliveira, D.M.; Feigl, B.J.; Pimentel, L.G.; Lisboa, I.P.; Gmach, M.R.; Varanda, L.L.; Morais, M.C.; Satiro, L.S.; Popin, G.V.; et al. Crop residue harvest for bioenergy production and its implications on soil functioning and plant growth: A review. *Sci. Agric.* **2018**, *75*, 255–272. [CrossRef]
81. Murphy, B.W. Impact of soil organic matter on soil properties—A review with emphasis on Australian soils. *Soil Res.* **2015**, *53*, 605. [CrossRef]
82. Wang, Y.; Xu, J.; Shen, J.H.; Luo, Y.M.; Scheu, S.; Ke, X. Tillage, residue burning and crop rotation alter soil fungal community and water-stable aggregation in arable fields. *Soil Tillage Res.* **2010**, *107*, 71–79. [CrossRef]
83. Azooz, R.H.; Arshad, M.A. Soil infiltration and hydraulic conductivity under long-term no-tillage and conventional tillage systems. *Can. J. Soil Sci.* **1996**, *76*, 143–152. [CrossRef]
84. Castellanos-Navarrete, A.; Rodríguez, A.C.; de Goede, R.G.M.; Kooistra, M.J.; Sayre, K.D.; Brussaard, L.; Pulleman, M.M. Earthworm activity and soil structural changes under conservation agriculture in central Mexico. *Soil Tillage Res.* **2012**, *123*, 61–70. [CrossRef]
85. Govaerts, B.; Sayre, K.D.; Goudeseune, B.; De Corte, P.; Lichter, K.; Dendooven, L.; Deckers, J. Conservation agriculture as a sustainable option for the central Mexican highlands. *Soil Tillage Res.* **2009**, *103*, 222–230. [CrossRef]
86. Sithole, N.J.; Magwaza, L.S.; Thibaud, G.R. Long-term impact of no-till conservation agriculture and N-fertilizer on soil aggregate stability, infiltration and distribution of C in different size fractions. *Soil Tillage Res.* **2019**, *190*, 147–156. [CrossRef]
87. Thierfelder, C.; Wall, P.C. Rotation in conservation agriculture systems of Zambia: Effects on soil quality and water relations. *Exp. Agric.* **2010**, *46*, 309–325. [CrossRef]
88. Nyamangara, J.; Marondedze, A.; Masvaya, E.N.; Mawodza, T.; Nyawasha, R.; Nyengerai, K.; Tirivavi, R.; Nyamugafata, P.; Wuta, M. Influence of basin-based conservation agriculture on selected soil quality parameters under smallholder farming in Zimbabwe. *Soil Use Manag.* **2014**, *30*, 550–559. [CrossRef]
89. Zhang, H.; Niu, L.; Hu, K.; Hao, J.; Li, F.; Gao, Z.; Wang, X. Influence of tillage, straw-returning and mineral fertilization on the stability and associated organic content of soil aggregates in the North China Plain. *Agronomy* **2020**, *10*, 951. [CrossRef]
90. Eze, S.; Dougill, A.J.; Banwart, S.A.; Hermans, T.D.G.; Ligowe, I.S.; Thierfelder, C. Impacts of conservation agriculture on soil structure and hydraulic properties of Malawian agricultural systems. *Soil Tillage Res.* **2020**, *201*, 104639. [CrossRef]
91. Soane, B.D.; Ball, B.C.; Arvidsson, J.; Basch, G.; Moreno, F.; Roger-Estrade, J. No-till in northern, western and south-western Europe: A review of problems and opportunities for crop production and the environment. *Soil Tillage Res.* **2012**, *118*, 66–87. [CrossRef]
92. Somasundaram, J.; Salikram, M.; Sinha, N.K.; Mohanty, M.; Chaudhary, R.S.; Dalal, R.C.; Mitra, R.; Blaise, N.; Coumar, D.; Hati, V.; et al. Conservation agriculture effects on soil properties and crop productivity in a semiarid region of India. *Soil Res.* **2019**, *57*, 187–199. [CrossRef]
93. Mloza-Banda, H.R.; Makwiza, C.N.; Mloza-Banda, M.L. Soil properties after conversion to conservation agriculture from ridge tillage in Southern Malawi. *J. Arid Environ.* **2016**, *127*, 7–16. [CrossRef]
94. Gómez-Muñoz, B.; Jensen, L.S.; Munkholm, L.; Olesen, J.E.; Møller Hansen, E.; Bruun, S. Long-term effect of tillage and straw retention in conservation agriculture systems on soil carbon storage. *Soil Sci. Soc. Am. J.* **2021**, *85*, 1465–1478. [CrossRef]

95. Cheesman, S.; Thierfelder, C.; Eash, N.S.; Kassie, G.T.; Frossard, E. Soil carbon stocks in conservation agriculture systems of Southern Africa. *Soil Tillage Res.* **2016**, *156*, 99–109. [CrossRef]
96. Li, Y.; Li, Z.; Cui, S.; Jagadamma, S.; Zhang, Q.P. Residue retention and minimum tillage improve physical environment of the soil in croplands: A global meta-analysis. *Soil Tillage Res.* **2019**, *194*, 104292. [CrossRef]
97. Mondal, S.; Mishra, J.S.; Poonia, S.P.; Kumar, R.; Dubey, R.; Kumar, S.; Verma, M.; Rao, K.K.; Ahmed, A.; Dwivedi, S.; et al. Can yield, soil C and aggregation be improved under long-term conservation agriculture in the eastern Indo-Gangetic plain of India? *Eur. J. Soil Sci.* **2021**, *72*, 1742–1761. [CrossRef]
98. Laborde, J.P.; Wortmann, C.S.; Blanco-Canqui, H.; McDonald, A.J.; Baigorria, G.A.; Lindquist, J.L. Short-term impacts of conservation agriculture on soil physical properties and productivity in the Midhills of Nepal. *Agron. J.* **2019**, *111*, 2128–2139. [CrossRef]
99. Kay, B.D.; VandenBygaart, A.J. Conservation tillage and depth stratification of porosity and soil organic matter. *Soil Tillage Res.* **2002**, *66*, 107–118. [CrossRef]
100. He, J.; Kuhn, N.J.; Zhang, X.M.; Zhang, X.R.; Li, H.W. Effects of 10 years of conservation tillage on soil properties and productivity in the farming–pastoral ecotone of Inner Mongolia, China. *Soil Use Manag.* **2009**, *25*, 201–209. [CrossRef]
101. Nyamadzawo, G.; Chikowo, R.; Nyamugafata, P.; Giller, K.E. Improved legume tree fallows and tillage effects on structural stability and infiltration rates of a kaolinitic sandy soil from central Zimbabwe. *Soil Tillage Res.* **2007**, *96*, 182–194. [CrossRef]
102. Mondal, S.; Poonia, S.P.; Mishra, J.S.; Bhatt, B.P.; Karnena, K.R.; Saurabh, K.; Rakesh, K.; Chakraborty, D. Short-term (5 years) impact of conservation agriculture on soil physical properties and organic carbon in a rice–wheat rotation in the indo-Gangetic plains of Bihar. *Eur. J. Soil Sci.* **2019**, *71*, 1076–1089. [CrossRef]
103. Islam, R.; Reeder, R. No-till and conservation agriculture in the United States: An example from the David Brandt farm, Carroll, Ohio. *Int. Soil Water Conserv. Res.* **2014**, *2*, 97–107. [CrossRef]
104. Parihar, C.M.; Yadav, M.R.; Jat, S.L.; Singh, A.K.; Kumar, B.; Pradhan, S.; Chakraborty, D.; Jat, M.L.; Jat, R.K.; Saharawat, Y.S.; et al. Long term effect of conservation agriculture in maize rotations on total organic carbon, physical and biological properties of a sandy loam soil in north-western Indo-Gangetic Plains. *Soil Tillage Res.* **2016**, *161*, 116–128. [CrossRef]
105. Gucci, R.; Caruso, G.; Bertolla, C.; Urbani, S.; Taticchi, A.; Esposto, S.; Servili, M.; Sifola, M.I.; Pellegrini, S.; Pagliai, M.; et al. Changes of soil properties and tree performance induced by soil management in a high-density olive orchard. *Eur. J. Agron.* **2012**, *41*, 18–27. [CrossRef]
106. Blanco-Canqui, H.; Lal, R. Crop residue removal impacts on soil productivity and environmental quality. *CRC Crit. Rev. Plant Sci.* **2009**, *28*, 139–163. [CrossRef]
107. Lahmar, R. Adoption of conservation agriculture in Europe: Lessons of the KASSA project. *Land Use Policy* **2010**, *27*, 4–10. [CrossRef]
108. Usón, A.; Poch, R.M. Effects of tillage and management practices on soil crust morphology under a Mediterranean environment. *Soil Tillage Res.* **2000**, *54*, 191–196. [CrossRef]
109. Baudron, F.; Tittonell, P.; Corbeels, M.; Letourmy, P.; Giller, K.E. Comparative performance of conservation agriculture and current smallholder farming practices in semi-arid Zimbabwe. *Field Crops Res.* **2012**, *132*, 117–128. [CrossRef]
110. Baumhardt, R.L.; Lascano, R.J. Rain infiltration as affected by wheat residue amount and distribution in ridged tillage. *Soil Sci. Soc. Am. J.* **1996**, *60*, 1908–1913. [CrossRef]
111. Page, K.L.; Dang, Y.P.; Dalal, R.C. The ability of conservation agriculture to conserve soil organic carbon and the subsequent impact on soil physical, chemical, and biological properties and yield. *Front. Sustain. Food Syst.* **2020**, *4*, 31. [CrossRef]
112. Dang, Y.P.; Seymour, N.P.; Walker, S.R.; Bell, M.J.; Freebairn, D.M. Strategic tillage in no-till farming systems in Australia's northern grains-growing regions: I. Drivers and implementation. *Soil Tillage Res.* **2015**, *152*, 104–114. [CrossRef]
113. Ruan, H.X.; Ahuja, L.R.; Green, T.R.; Benjamın, J.G. Residue cover and surface-sealing effects on infiltration: Numerical simulations for field applications. *Soil Sci. Soc. Am. J.* **2001**, *65*, 853–861. [CrossRef]
114. McGarry, D.; Bridge, B.J.; Radford, B.J. Contrasting soil physical properties after zero and traditional tillage of an alluvial soil in the semi-arid subtropics. *Soil Tillage Res.* **2000**, *53*, 105–115. [CrossRef]
115. Verhulst, N.; Carrillo, G.A.; Moeller, C.; Trethowan, R.; Sayre, K.D.; Govaerts, B. Conservation agriculture for wheat-based cropping systems under gravity irrigation: Increasing resilience through improved soil quality. *Plant Soil* **2011**, *340*, 467–479. [CrossRef]
116. Govaerts, B.; Sayre, K.D.; Deckers, J. Stable high yields with zero tillage and permanent bed planting? *Field Crops Res.* **2005**, *94*, 33–42. [CrossRef]
117. Stagnari, F.; Ramazzotti, S.; Pisante, M. Conservation agriculture: A different approach for crop production through sustainable soil and water management: A Review. In *Organic Farming, Pest Control and Remediation of Soil Pollutants*; Lichtfouse, E., Ed.; Sustainable Agriculture Reviews; Springer: Dordrecht, The Netherlands, 2009; Volume 1, pp. 55–83. [CrossRef]
118. Mondal, S.; Das, T.K.; Thomas, P.; Mishra, A.; Bandyopadhyay, K.; Aggarwal, P.; Chakraborty, D. Effect of conservation agriculture on soil hydro-physical properties, total and particulate organic carbon and root morphology in wheat (*Triticum aestivum*) under rice (*Oryza sativa*)-wheat system. *Indian J. Agric. Sci.* **2019**, *89*, 46–55.
119. Hamza, M.A.; Anderson, W.K. Soil compaction in cropping systems: A review of the nature, causes and possible solutions. *Soil Tillage Res.* **2005**, *82*, 121–145. [CrossRef]

120. Chen, G.; Weil, R.R. Root growth and yield of maize as affected by soil compaction and cover crops. *Soil Tillage Res.* **2011**, *117*, 17–27. [CrossRef]
121. Munkholm, L.J.; Schjønning, P.; Rasmussen, K.J.; Tanderup, K. Spatial and temporal effects of direct drilling on soil structure in the seedling environment. *Soil Tillage Res.* **2003**, *71*, 163–173. [CrossRef]
122. Van den Putte, A.; Govers, G.; Diels, J.; Gillijns, K.; Demuzere, M. Assessing the effect of soil tillage on crop growth: A meta-regression analysis on European crop yields under conservation agriculture. *Eur. J. Agron.* **2010**, *33*, 231–241. [CrossRef]
123. Moreno, F.; Arrúe, J.L.; Cantero-Martínez, C.; López, M.V.; Murillo, J.M.; Sombrero, A.; López-Garrido, R.; Madejón, E.; Moret, D.; Álvaro-Fuentes, J. Conservation agriculture under Mediterranean conditions in Spain. In *Biodiversity, Biofuels, Agroforestry and Conservation Agriculture*; Lichtfouse, E., Ed.; Sustainable Agriculture Reviews; Springer: Dordrecht, The Netherlands, 2010; Volume 5, pp. 175–193. [CrossRef]
124. Wortmann, C.S.; Drijber, R.A.; Franti, T.G. One-time tillage of no-till crop land five years post-tillage. *Agron. J.* **2010**, *102*, 1302–1307. [CrossRef]
125. Gosling, S.N.; Arnell, N.W. A global assessment of the impact of climate change on water scarcity. *Clim. Chang.* **2016**, *134*, 371–385. [CrossRef]
126. Verhulst, N.; Sayre, K.D.; Vargas, M.; Crossa, J.; Deckers, J.; Raes, D.; Govaerts, B. Wheat yield and tillage–straw management system × year interaction explained by climatic co-variables for an irrigated bed planting system in north-western Mexico. *Field Crops Res.* **2011**, *124*, 347–356. [CrossRef]
127. Ghosh, B.N.; Dogra, P.; Sharma, N.K.; Bhattacharyya, R.; Mishra, P.K. Conservation agriculture impact for soil conservation in maize–wheat cropping system in the Indian sub-Himalayas. *Int. Soil Water Conserv. Res.* **2015**, *3*, 112–118. [CrossRef]
128. Sławiński, C.; Cymerman, J.; Witkowska-Walczak, B.; Lamorski, K. Impact of diverse tillage on soil moisture dynamics. *Int. Agrophys.* **2015**, *26*, 301–309. [CrossRef]
129. Thierfelder, C.; Wall, P.C. Investigating conservation agriculture (CA) systems in Zambia and Zimbabwe to mitigate future effects of climate change. *J. Crop. Improv.* **2010**, *24*, 113–121. [CrossRef]
130. Busari, A.M.; Salako, F.K.; Tuniz, C.; Zuppi, G.M.; Stenni, B.; Adetunji, M.T.; Arowolo, T.A. Estimation of soil water evaporative loss after tillage operation using the stable isotope technique. *Int. Agrophys.* **2013**, *27*, 257–264. [CrossRef]
131. Parihar, C.M.; Nayak, H.S.; Rai, V.K.; Jat, S.L.; Parihar, N.; Aggarwal, P.; Mishra, A.K. Soil water dynamics, water productivity and radiation use efficiency of maize under multi-year conservation agriculture during contrasting rainfall events. *Field Crops Res.* **2019**, *241*, 107570. [CrossRef]
132. TerAvest, D.; Carpenter-Boggs, L.; Thierfelder, C.; Reganold, J.P. Crop production and soil water management in conservation agriculture, no-till, and conventional tillage systems in Malawi. *Agric. Ecosyst. Environ.* **2015**, *212*, 285–296. [CrossRef]
133. Zhao, X.; Liu, B.Y.; Liu, S.L.; Qi, J.Y.; Wang, X.; Pu, C.; Li, S.S.; Zhang, X.Z.; Yang, X.G.; Lal, R.; et al. Sustaining crop production in China's cropland by crop residue retention: A meta-analysis. *Land Degrad. Dev.* **2020**, *31*, 694–709. [CrossRef]
134. Ghosh, P.K.; Das, A.; Saha, R.; Kharkrang, E.; Tripathi, A.K.; Munda, G.C.; Ngachan, S.V. Conservation agriculture towards achieving food security in North East India. *Curr. Sci.* **2010**, *99*, 915–922.
135. Mondal, S.; Chakraborty, D.; Das, T.K.; Shrivastava, M.; Mishra, A.K.; Bandyopadhyay, K.K.; Aggarwal, P.; Chaudhari, S.K. Conservation agriculture had a strong impact on the sub-surface soil strength and root growth in wheat after a 7-year transition period. *Soil Tillage Res.* **2019**, *195*, 104385. [CrossRef]
136. Chalise, K.S.; Singh, S.; Wegner, B.R.; Kumar, S.; Pérez, G.J.D.; Osborne, S.L.; Nleya, T.; Guzman, J.; Rohila, J.S. Cover crops and returning residue impact on soil organic carbon, bulk density, penetration resistance, water retention, infiltration, and soybean yield. *Agron. J.* **2018**, *110*, 99–108. [CrossRef]
137. Mutuku, E.A.; Roobroeck, D.; Vanlauwe, B.; Boeckx, P.; Cornelis, W.M. Maize production under combined conservation agriculture and integrated soil fertility management in the sub-humid and semi-arid regions of Kenya. *Field Crops Res.* **2020**, *254*, 107833. [CrossRef]
138. Sindelar, M.; Blanco-Canqui, H.; Jin, V.L.; Ferguson, R.B. Cover crops and corn residue removal: Impacts on soil hydraulic properties and their relationships with carbon. *Soil Sci. Soc. Am. J.* **2019**, *83*, 221–231. [CrossRef]
139. Choudhary, M.; Rana, K.S.; Meena, M.C.; Bana, R.S.; Jakhar, P.; Ghasal, P.C.; Verma, R.K. Changes in physico-chemical and biological properties of soil under conservation agriculture based pearl millet–mustard cropping system in rainfed semi-arid region. *Arch. Agron. Soil Sci.* **2019**, *65*, 911–927. [CrossRef]
140. Singh, B.; Eberbach, P.L.; Humphreys, E.; Kukal, S.S. The effect of rice straw mulch on evapotranspiration, transpiration and soil evaporation of irrigated wheat in Punjab, India. *Field Crops Res.* **2011**, *98*, 1847–1855. [CrossRef]
141. Gupta, R.; Sayre, K. Conservation agriculture in South Asia. *J. Agric. Sci.* **2007**, *145*, 207–214. [CrossRef]
142. Assefa, T.; Jha, M.; Reyes, M.; Worqlul, A.W. Modeling the impacts of conservation agriculture with a drip irrigation system on the hydrology and water management in Sub-Saharan Africa. *Sustainability* **2018**, *10*, 4763. [CrossRef]
143. Belay, S.A.; Schmitter, P.; Worqlul, A.W.; Steenhuis, T.S.; Reyes, M.R.; Tilahun, S.A. Conservation agriculture saves irrigation water in the dry monsoon phase in the Ethiopian Highlands. *Water* **2019**, *11*, 2103. [CrossRef]
144. Jat, H.S.; Kumar, V.; Datta, A.; Choudhary, M.; Singh, Y.; Kakraliya, S.K.; Poonia, T.; McDonald, A.J.; Jat, M.L.; Sharma, P.C. Designing profitable, resource use efficient and environmentally sound cereal based systems for the Western Indo-Gangetic plains. *Sci. Rep.* **2020**, *10*, 19267. [CrossRef] [PubMed]

145. Alvarez, R.; Steinbach, H. A review of the effects of tillage systems on some soil physical properties, water content, nitrate availability and crops yield in the Argentine Pampas. *Soil Tillage Res.* **2009**, *104*, 1–15. [CrossRef]
146. Pittelkow, C.M.; Liang, X.Q.; Linquist, B.A.; van Groenigen, K.J.; Lee, J.; Lundy, M.E.; van Gestel, N.; Six, J.; Venterea, R.T.; van Kessel, C. Productivity limits and potentials of the principles of conservation agriculture. *Nature* **2015**, *517*, 365–368. [CrossRef]
147. Zhao, X.; Liu, S.; Pu, C.; Zhang, X.; Xue, J.; Ren, Y.; Zhao, X.; Chen, F.; Lal, R.; Zhang, H. Crop yields under no-till farming in China: A meta-analysis. *Eur. J. Agron.* **2017**, *84*, 67–75. [CrossRef]
148. Lu, X. A meta-analysis of the effects of crop residue return on crop yields and water use efficiency. *PLoS ONE* **2020**, *15*, e0231740. [CrossRef]
149. Sun, L.; Wang, S.; Zhang, Y.; Li, J.; Wang, X.; Wang, R.; Lyu, W.; Chen, N.; Wang, Q. Conservation agriculture based on crop rotation and tillage in the semi-arid Loess Plateau, China: Effects on crop yield and soil water use. *Agric. Ecosyst. Environ.* **2018**, *251*, 67–77. [CrossRef]
150. Das, T.K.; Bandyopadhyay, K.K.; Bhattacharyya, R.; Sudhishri, S.; Sharma, A.R.; Behera, U.K.; Saharawat, Y.S.; Sahoo, P.K.; Pathak, H.; Vyas, A.K.; et al. Effects of conservation agriculture on crop productivity and water-use efficiency under an irrigated pigeonpea–wheat cropping system in the western Indo-Gangetic Plains. *J. Agric. Sci.* **2016**, *154*, 1327–1342. [CrossRef]
151. Rockström, J.; Kaumbutho, P.; Mwalley, J.; Nzabi, A.W.; Temesgen, M.; Mawenya, L.; Barron, J.; Mutua, J.; Damgaard-Larsen, S. Conservation farming strategies in East and Southern Africa: Yields and rain water productivity from on-farm action research. *Soil Tillage Res.* **2009**, *103*, 23–32. [CrossRef]
152. Milgroom, J.; Soriano, M.A.; Garrido, J.M.; Gómez, J.A.; Fereres, E. The influence of a shift from conventional to organic olive farming on soil management and erosion risk in Southern Spain. *Renew. Agric. Food Syst.* **2007**, *22*, 1–10. [CrossRef]
153. Correia, C.M.; Brito, C.; Sampaio, A.; Dias, A.A.; Bacelar, E.; Gonçalves, B.; Ferreira, H.; Moutinho, P.J.; Rodrigues, M.A. Leguminous cover crops improve the profitability and the sustainability of rainfed olive (*Olea europaea* L.) orchards: From soil biology to physiology of yield determination. *Procedia Environ. Sci.* **2015**, *29*, 282–283. [CrossRef]
154. Arampatzis, G.; Hatzigiannakis, E.; Pisinaras, V.; Kourgialas, N.; Psarras, G.; Kinigopoulou, V.; Panagopoulos, A.; Koubouris, G. Soil water content and olive tree yield responses to soil management, irrigation, and precipitation in a hilly Mediterranean area. *J. Water Clim. Chang.* **2018**, *9*, 672–678. [CrossRef]
155. Krstić, Đ.; Vujić, S.; Jaćimović, G.; D'Ottavio, P.; Radanović, Z.; Erić, P.; Ćupina, B. The effect of cover crops on soil water balance in rain-fed conditions. *Atmosphere* **2018**, *9*, 492. [CrossRef]
156. Durán, Z.V.H.; Rodríguez, P.C.R.; Arroyo, P.L.; Martínez, R.A.; Francia, M.J.R.; Cárceles, R.B. Soil conservation measures in rainfed olive orchards in South-Eastern Spain: Impacts of plant strips on soil water dynamics. *Pedosphere* **2009**, *19*, 453–464. [CrossRef]
157. Castellini, M.; Stellacci, A.M.; Mastrangelo, M.; Caputo, F.; Manici, L.M. Estimating the soil hydraulic functions of some olive orchards: Soil management implications for water saving in soils of Salento peninsula (southern Italy). *Agronomy* **2020**, *10*, 177. [CrossRef]
158. Abazi, U.; Lorite, I.J.; Cárceles, R.B.; Martínez, R.A.; Durán, Z.V.H.; Francia, M.J.R.; Gómez, J.A. WABOL: A conceptual water balance model for analyzing rainfall water use in olive orchards under different soil and cover crop management strategies. *Comput. Electron. Agric.* **2013**, *91*, 35–48. [CrossRef]
159. Rusinamhodzi, L.; Corbeels, M.; van Wijk, M.T.; Rufino, M.C.; Nyamangara, J.; Giller, K.E. A meta-analysis of long-term effects of conservation agriculture on maize grain yield under rain-fed conditions. *Agron. Sustain. Dev.* **2011**, *31*, 657. [CrossRef]
160. Thierfelder, C.; Wall, P.C. Effects of conservation agriculture on soil quality and productivity in contrasting agro-ecological environments of Zimbabwe. *Soil Use Manag.* **2012**, *28*, 209–220. [CrossRef]
161. Montgomery, D.R. Soil erosion and agricultural sustainability. *Proc. Natl. Acad. Sci. USA* **2007**, *104*, 13268–13272. [CrossRef]
162. Cárceles, R.B.; Durán, Z.V.H.; Soriano, R.M.; Cermeño, S.P.; Gálvez, R.B.; Carbonell, B.R.; Ordoñez, F.R.; García, T.I.F. Soil and water conservation measures for Mediterranean fruit crops in rainfed hillslopes. In *Resources Use Efficiency in Agriculture*; Kumar, S., Meena, R.S., Jhariya, M.K., Eds.; Springer: Singapore, 2020; pp. 427–480. [CrossRef]
163. Durán, Z.V.H.; Rodríguez, P.C.R. Soil-erosion and runoff prevention by plant covers. A review. *Agron. Sustain. Dev.* **2008**, *28*, 65–86. [CrossRef]
164. Thierfelder, C.; Wall, P.C. Effects of conservation agriculture techniques on infiltration and soil water content in Zambia and Zimbabwe. *Soil Tillage Res.* **2009**, *105*, 217–227. [CrossRef]
165. Kurothe, R.S.; Kumar, G.; Singh, R.; Singh, H.B.; Tiwari, S.P.; Vishwakarma, A.K.; Sena, D.R.; Pande, V.C. Effect of tillage and cropping systems on runoff, soil loss and crop yields under semiarid rainfed agriculture in India. *Soil Tillage Res.* **2014**, *140*, 126–134. [CrossRef]
166. Panachuki, E.; Bertol, I.; Alves Sobrinho, T.; Sanches de Oliveira, P.T.; Bicca Rodrigues, D.B.B. Soil and water loss and water infiltration in red latosol under different management systems. *Rev. Bras. Cienc. Solo* **2011**, *35*, 1777–1785. [CrossRef]
167. Araya, T.; Cornelis, W.M.; Nyssen, J.; Govaerts, B.; Bauer, H.; Gebreegziabher, T.; Oicha, T.; Raes, D.; Sayre, K.D.; Haile, M.; et al. Effects of conservation agriculture on runoff, soil loss and crop yield under rainfed conditions in Tigray, Northern Ethiopia. *Soil Use Manag.* **2011**, *27*, 404–414. [CrossRef]
168. Ranaivoson, L.; Naudin, K.; Ripoche, A.; Affholder, F.; Rabeharisoa, L.; Corbeels, M. Agro-ecological functions of crop residues under conservation agriculture. A review. *Agron. Sustain. Dev.* **2017**, *37*, 26. [CrossRef]

169. Scopel, E.; Findeling, A.; Chavez Guerra, E.; Corbeels, M. Impact of direct sowing mulch-based cropping systems on soil carbon, soil erosion and maize yield. *Agron. Sustain. Dev.* **2005**, *25*, 425–432. [CrossRef]
170. Du, X.; Jian, J.; Du, C.; Stewart, R.D. Conservation management decreases surface runoff and soil erosion. *Int. Soil Water Conserv. Res.* **2022**, *10*, 188–196. [CrossRef]
171. Gebreegziabher, T.; Nyssen, J.; Govaerts, B.; Getnet, F.; Behailu, M.; Haile, M.; Deckers, J. Contour furrows for in situ soil and water conservation, Tigray, Northern Ethiopia. *Soil Tillage Res.* **2009**, *103*, 257–264. [CrossRef]
172. Lanckriet, S.; Araya, T.; Cornelis, W.; Verfaillie, E.; Poesen, J.; Govaerts, B.; Bauer, H.; Deckers, J.; Haile, M.; Nyssen, J. Impact of conservation agriculture on catchment runoff and soil loss under changing climate conditions in May Zeg-zeg (Ethiopia). *J. Hydrol.* **2012**, *475*, 336–349. [CrossRef]
173. Deng, C.; Zhang, G.; Liu, Y.; Nie, X.; Li, Z.; Liu, J.; Zhu, D. Advantages and disadvantages of terracing: A comprehensive review. *Int. Soil Water Conserv. Res.* **2021**, *9*, 344–359. [CrossRef]
174. Durán, Z.V.H.; Aguilar, R.J.; Martínez, R.A.; Franco, T.D. Impact of erosion in the taluses of subtropical orchard terraces. *Agric. Ecosyst. Environ.* **2005**, *107*, 199–210. [CrossRef]
175. Durán, Z.V.H.; Rodríguez, P.C.R.; Martin, P.F.J.; de Graaff, J.; Francia, M.J.R.; Flanagan, D.C. Environmental impact of introducing plant covers in the taluses of terraces: Implications for mitigating agricultural soil erosion and runoff. *Catena* **2011**, *84*, 79–88. [CrossRef]
176. Francia, M.J.R.; Durán, Z.V.H.; Martínez, R.A. Environmental impact from mountainous olive orchards under different soil-management systems (SE Spain). *Sci. Total Environ.* **2006**, *358*, 46–60. [CrossRef] [PubMed]
177. Gómez, J.A.; Sobrinho, T.A.; Giráldez, J.V.; Fereres, E. Soil management effects on runoff, erosion and soil properties in an olive grove of Southern Spain. *Soil Tillage Res.* **2009**, *102*, 5–13. [CrossRef]
178. Cárceles, B.; Durán, Z.V.H.; Soriano, R.M.; Gálvez, R.B.; García, T.I.F. Soil erosion and the effectiveness of the conservation measures in Mediterranean hillslope farming (SE Spain). *Eurasian Soil Sci.* **2021**, *54*, 792–806. [CrossRef]
179. Blanco-Canqui, H.; Ruis, S.J. No-tillage and soil physical environment. *Geoderma* **2018**, *326*, 164–200. [CrossRef]
180. Sarkar, S.; Paramanick, M.; Goswami, S.B. Soil temperature, water use and yield of yellow sarson (*Brassica napus* L. var. *glauca) in relation to tillage intensity and mulch management under rainfed lowland ecosystem in eastern India. Soil Tillage Res.* **2007**, *93*, 94–101. [CrossRef]
181. Rai, V.; Pramanik, P.; Das, T.K.; Aggarwal, P.; Bhattacharyya, R.; Krishnan, P.; Sehgal, V.K. Modelling soil hydrothermal regimes in pigeon pea under conservation agriculture using Hydrus-2D. *Soil Tillage Res.* **2019**, *190*, 92–108. [CrossRef]
182. Sharratt, B.S.; Campbell, G.S. Radiation balance of a soil-straw surface modified by straw color. *Agron. J.* **1994**, *86*, 200–203. [CrossRef]
183. Verhulst, N.; Govaerts, B.; Verachtert, E.; Castellanos-Navarrete, A.; Mezzalama, M.; Wall, P.; Deckers, J.; Sayre, K.D. Conservation agriculture, improving soil quality for sustainable production systems? In *Advances in Soil Science: Food Security and Soil Quality*; Lal, R., Stewart, B.A., Eds.; CRC Press: Boca Raton, FL, USA, 2010; pp. 137–208.
184. Li, R.; Hou, X.; Jia, Z.; Han, Q.; Ren, X.; Yang, B. Effects on soil temperature, moisture, and corn yield of cultivation with ridge and furrow mulching in the rainfed area of the Loess Plateau, China. *Agric. Water Manag.* **2013**, *116*, 101–109. [CrossRef]
185. Chen, S.Y.; Zhang, X.Y.; Pei, D.; Sun, H.Y. Effects of corn straw mulching on soil temperature and soil evaporation of winter wheat field. *Trans. CSAE* **2005**, *21*, 171–173.
186. Acharya, C.L.; Kapur, O.C.; Dixit, S.P. Moisture conservation for rainfed wheat production with alternative mulches and conservation tillage in the hills of north-west India. *Soil Tillage Res.* **1998**, *46*, 153–163. [CrossRef]
187. Gupta, S.C.; Larson, W.E.; Linden, D.R. Tillage and surface residue effects on soil upper boundary temperatures. *Soil Sci. Soc. Am. J.* **1983**, *47*, 1212–1218. [CrossRef]
188. Guzman, J.G.; Al-Kaisi, M. Residue removal and management practices effects on soil environment and carbon budget. *Soil Sci. Soc. Am. J.* **2014**, *78*, 609–623. [CrossRef]
189. Oliveira, J.; Timm, L.; Tominaga, T.; Cássaro, F.A.M.; Reichardt, K.; Bacchi, O.O.S.; Dourado-Neto, D.; Câmara, G.M. de S. Soil temperature in a sugar-cane crop as a function of the management system. *Plant Soil* **2001**, *230*, 61–66. [CrossRef]
190. Steward, P.R.; Dougill, A.J.; Thierfelder, C.; Pittelkow, C.M.; Stringer, L.C.; Kudzala, M.; Sheckelford, G.E. The adaptive capacity of maize-based conservation agriculture systems to climate stress in tropical and subtropical environments: A meta-regression of yields. *Agric. Ecosyst. Environ.* **2018**, *251*, 194–202. [CrossRef]
191. Kaspar, T.C.; Erbach, D.C.; Cruse, R.M. Corn response to seed-row residue removal. *Soil Sci. Soc. Am. J.* **1990**, *54*, 1112–1117. [CrossRef]
192. Chen, S.Y.; Zhang, X.Y.; Pei, D.; Sun, H.Y.; Chen, S. Effects of straw mulching on soil temperature, evaporation and yield of winter wheat: Field experiments on the North China Plain. *Ann. Appl. Biol.* **2007**, *150*, 261–268. [CrossRef]
193. Fortin, M.C. Soil temperature, soil water, and no-till corn development following in-row residue removal. *Agron. J.* **1993**, *85*, 571–576. [CrossRef]
194. Radke, J.K. Managing early season soil temperatures in the northern corn belt using configured soil surfaces and mulches. *Soil Sci. Soc. Am. J.* **1982**, *46*, 1067–1071. [CrossRef]
195. Shen, Y.; McLaughlin, N.; Zhang, X.; Xu, M.; Liang, A. Effect of tillage and crop residue on soil temperature following planting for a Black soil in Northeast China. *Sci. Rep.* **2018**, *8*, 4500. [CrossRef] [PubMed]

196. Franzluebbers, A.J.; Hons, F.M.; Zuberer, D.A. Tillage-induced seasonal changes in soil physical properties affecting soil CO_2 evolution under intensive cropping. *Soil Tillage Res.* **1995**, *34*, 41–60. [CrossRef]
197. Kahimba, F.; Sri Ranjan, R.; Froese, J.; Entz, M.; Nason, R. Cover crop effects on infiltration, soil temperature, and soil moisture distribution in the Canadian prairies. *Appl. Eng. Agric.* **2008**, *24*, 321–333. [CrossRef]
198. Al-Darby, A.M.; Lowery, B.; Daniel, T.C. Corn leaf water potential and water use efficiency under three conservation tillage systems. *Soil Tillage Res.* **1987**, *9*, 241–254. [CrossRef]
199. Reeves, D.W. The role of soil organic matter in maintaining soil quality in continuous cropping systems. *Soil Tillage Res.* **1997**, *43*, 131–167. [CrossRef]
200. Fageria, N.K. Role of soil organic matter in maintaining sustainability of cropping systems. *Commun. Soil Sci. Plant Anal.* **2012**, *43*, 2063–2113. [CrossRef]
201. Chenu, C.; Angers, D.A.; Barré, P.; Derrien, D.; Arrouays, D.; Balesdent, J. Increasing organic stocks in agricultural soils: Knowledge gaps and potential innovations. *Soil Tillage Res.* **2018**, *188*, 41–52. [CrossRef]
202. Valkama, E.; Kunypiyaeva, G.; Zhapayev, R.; Karabayev, M.; Zhusupbekov, E.; Perego, A.; Schillaci, C.; Sacco, D.; Moretti, B.; Grignani, C.; et al. Can conservation agriculture increase soil carbon sequestration? A modelling approach. *Geoderma* **2020**, *369*, 114298. [CrossRef]
203. Powlson, D.S.; Stirling, C.M.; Thierfelder, K.C.; Rodger, P.; White, R.P.; Jat, M.L. Does conservation agriculture deliver climate change mitigation through soil carbon sequestration in tropical agro-ecosystems? *Agric. Ecosyst. Environ.* **2016**, *220*, 164–174. [CrossRef]
204. Balesdent, J.; Chenu, C.; Balabane, M. Relationship of soil organic matter dynamics to physical protection and tillage. *Soil Tillage Res.* **2000**, *53*, 215–230. [CrossRef]
205. Repullo-Ruibérriz de Torres, M.A.; Carbonell, B.R.M.; Moreno, G.M.; Ordóñez, F.R.; Rodríguez, L.A. Soil organic matter and nutrient improvement through cover crops in a Mediterranean olive orchard. *Soil Tillage Res.* **2021**, *210*, 104977. [CrossRef]
206. Lal, R. Soil carbon sequestration to mitigate climate change. *Geoderma* **2004**, *123*, 1–22. [CrossRef]
207. Six, J.; Ogle, S.M.; Breidt, F.J.; Conant, R.T.; Mosiers, A.R.; Paustian, K. The potential to mitigate global warming with no-tillage management is only realized when practised in the long term. *Glob. Chang. Biol.* **2004**, *10*, 155–160. [CrossRef]
208. González-Sánchez, E.J.; Ordóñez, F.R.; Carbonell, B.R.; Veroz, G.O.; Gil, R.J.A. Meta-analysis on atmospheric carbon capture in Spain through the use of conservation agriculture. *Soil Tillage Res.* **2012**, *122*, 52–60. [CrossRef]
209. Luo, Z.; Wang, E.; Sun, O.J. Can no-tillage stimulate carbon sequestration in agricultural soils? A meta-analysis of paired experiments. *Agric. Ecosyst. Environ.* **2010**, *139*, 224–231. [CrossRef]
210. Mondal, S.; Chakraborty, D.; Bandyopadhyay, K.; Aggarwal, P.; Rana, D.S. A global analysis of the impact of zero-tillage on soil physical condition, organic carbon content, and plant root response. *Land Degrad. Dev.* **2020**, *31*, 557–567. [CrossRef]
211. Camarotto, C.; Piccoli, I.; Dal Ferro, N.; Polese, R.; Chiarini, F.; Furlan, L.; Morari, F. Have we reached the turning point? Looking for evidence of SOC increase under conservation agriculture and cover crop practices. *Eur. J. Soil Sci.* **2020**, *71*, 1050–1063. [CrossRef]
212. Pooniya, V.; Biswakarma, N.; Parihar, C.M.; Swarnalakshmi, K.; Lama, A.; Zhiipao, R.R.; Nath, A.; Pal, M.; Jat, S.L.; Satyanarayana, T.; et al. Six years of conservation agriculture and nutrient management in maize–mustard rotation: Impact on soil properties, system productivity and profitability. *Field Crops Res.* **2021**, *260*, 108002. [CrossRef]
213. VandenBygaart, A.J.; Angers, D.A. Towards accurate measurements of soil organic carbon stock change in agroecosystems. *Can. J. Soil. Sci.* **2006**, *86*, 465–471. [CrossRef]
214. Repullo-Ruibérriz de Torres, M.A.; Moreno, G.M.; Ordóñez, F.R.; Rodríguez, L.A.; Cárceles, R.B.; García, T.I.F.; Durán, Z.V.H.; Carbonell, B.R.M. Cover crop contributions to improve the soil nitrogen and carbon sequestration in almond orchards (SW Spain). *Agronomy* **2021**, *11*, 387. [CrossRef]
215. Roy, D.; Datta, A.; Jat, H.S.; Choudhary, M.; Sharma, P.C.; Singh, P.K.; Jat, M.L. Impact of long term conservation agriculture on soil quality under cereal based systems of North West India. *Geoderma* **2022**, *405*, 115391. [CrossRef]
216. Perego, A.; Rocca, A.; Cattivelli, V.; Tabaglio, V.; Fiorini, A.; Barbieri, S.; Schillaci, C.; Chiodini, M.E.; Brenna, S.; Acutis, M. Agro-environmental aspects of conservation agriculture compared to conventional systems: A 3-year experience on 20 farms in the Po valley (Northern Italy). *Agric. Syst.* **2019**, *168*, 73–87. [CrossRef]
217. Patra, S.; Julich, S.; Feger, K.H.; Jat, M.L.; Sharma, P.C.; Schwärzel, K. Effect of conservation agriculture on stratification of soil organic matter under cereal-based cropping systems. *Arch. Agron. Soil Sci.* **2019**, *65*, 2013–2028. [CrossRef]
218. Li, Y.; Li, Z.; Chang, S.X.; Cui, S.; Jagadamma, S.; Zhang, Q.; Cai, Y. Residue retention promotes soil carbon accumulation in minimum tillage systems: Implications for conservation agriculture. *Sci. Total Environ.* **2020**, *740*, 140147. [CrossRef] [PubMed]
219. Sapkota, T.B.; Jat, R.K.; Singh, R.G.; Jat, M.L.; Stirling, C.M.; Jat, M.K.; Bijarniya, D.; Kumar, M.; Saharawat, Y.S.; Gupta, R.K. Soil organic carbon changes after seven years of conservation agriculture in a rice–wheat system of the eastern Indo-Gangetic Plains. *Soil Use Manag.* **2017**, *33*, 81–89. [CrossRef]
220. Butterly, C.R.; Kaudal, B.B.; Baldock, J.A.; Tang, C. Contribution of soluble and insoluble fractions of agricultural residues to short-term pH changes. *Eur. J. Soil Sci.* **2011**, *62*, 718–727. [CrossRef]
221. Xu, R.K.; Coventry, D.R. Soil pH changes associated with lupin and wheat plant materials incorporated in a red-brown earth soil. *Plant Soil* **2003**, *250*, 113–119. [CrossRef]

222. Xu, J.M.; Tang, C.; Chen, Z.L. The role of plant residues in pH change of acid soils differing in initial pH. *Soil Biol. Biochem.* **2006**, *38*, 709–719. [CrossRef]
223. Muchabi, J.; Lungu, O.I.; Mweetwa, A.M. Conservation agriculture in Zambia: Effects on selected soil properties and biological nitrogen fixation in soya beans (*Glycine max* (L.) Merr). *Sustain. Agric. Res.* **2014**, *3*, 28–36. [CrossRef]
224. Duiker, S.W.; Beegle, D.B. Soil fertility distributions in long-term no-till, chisel/disk and moldboard plow/disk systems. *Soil Tillage Res.* **2006**, *88*, 30–41. [CrossRef]
225. Umar, B.B.; Aune, B.J.; Johnsen, H.F.; Lungu, I.O. Options for improving smallholder conservation agriculture in Zambia. *J. Agric. Sci.* **2011**, *3*, 50–62. [CrossRef]
226. Sinha, A.K.; Ghosh, A.; Dhar, T.; Bhattacharya, P.M.; Mitra, B.; Rakesh, S.; Paneru, P.; Shrestha, S.R.; Manandhar, S.; Beura, S.; et al. Trends in key soil parameters under conservation agriculture-based sustainable intensification farming practices in the Eastern Ganga Alluvial Plains. *Soil Res.* **2019**, *57*, 883–893. [CrossRef]
227. Limousin, G.; Tessier, D. Effects of no-tillage on chemical gradients and topsoil acidification. *Soil Tillage Res.* **2007**, *92*, 167–174. [CrossRef]
228. Sithole, N.J.; Magwaza, L.S. Long-term changes of soil chemical characteristics and maize yield in no-till conservation agriculture in a semi-arid environment of South Africa. *Soil Tillage Res.* **2019**, *194*, 104317. [CrossRef]
229. Butterly, C.R.; Baldock, J.A.; Tang, C. The contribution of crop residues to changes in soil pH under field conditions. *Plant Soil* **2013**, *366*, 185–198. [CrossRef]
230. Husson, O.; Brunet, A.; Babre, D.; Charpentier, H.; Durand, M.; Sarthou, J.P. Conservation agriculture systems alter the electrical characteristics (Eh, pH and EC) of four soil types in France. *Soil Tillage Res.* **2018**, *176*, 57–68. [CrossRef]
231. Ligowe, S.I.; Nalivata, C.P.; Njoloma, J.; Makumba, W.; Thierfelder, C. Medium-term effects of conservation agriculture on soil quality. *Afr. J. Agric. Res.* **2017**, *12*, 2412–2420. [CrossRef]
232. Rashidi, M.; Seilsepour, M. Modeling of soil cation exchange capacity based on soil organic carbon. *ARPN J. Agric. Biol. Sci.* **2008**, *3*, 41–45.
233. Sá, J.C.D.; Cerri, C.C.; Lal, R.; Dick, W.A.; Piccolo, M.D.; Feigl, B.E. Soil organic carbon and fertility interactions affected by a tillage chronosequence in a Brazilian Oxisol. *Soil Tillage Res.* **2009**, *104*, 56–64. [CrossRef]
234. Ben Moussa-Machraoui, S.; Errouissi, F.; Ben-Hammonda, M.; Nouira, S. Comparative effects of conventional and no-tillage management on some soil properties under Mediterranean semi-arid conditions in north western Tunisia. *Soil Tillage Res.* **2010**, *106*, 247–253. [CrossRef]
235. Williams, A.; Jordan, N.R.; Smith, R.G.; Hunter, M.C.; Kammerer, M.; Kane, D.A.; Koide, R.T.; Davis, A.S. A regionally-adapted implementation of conservation agriculture delivers rapid improvements to soil properties associated with crop yield stability. *Sci. Rep.* **2018**, *8*, 8467. [CrossRef] [PubMed]
236. Ramos, F.T.; Dores, E.F.d.C.; Weber, O.L.d.S.; Beber, D.C.; Campelo, J.H., Jr.; Maia, J.C.d.S. Soil organic matter doubles the cation exchange capacity of tropical soil under no-till farming in Brazil. *J. Sci. Food Agric.* **2018**, *98*, 3595–3602. [CrossRef] [PubMed]
237. Govaerts, B.; Sayre, K.D.; Lichter, K.; Dendooven, L.; Deckers, J. Influence of permanent raised bed planting and residue management on physical and chemical soil quality in rain fed maize/wheat systems. *Plant Soil* **2007**, *291*, 39–54. [CrossRef]
238. Kumari, D.; Kumar, S.; Parveen, H.; Pradhan, A.K.; Kumar, S.; Kumari, R. Long-term impact of conservation agriculture on chemical properties of soil. *Int. J. Curr. Microbiol. Appl. Sci.* **2019**, *8*, 2144–2153. [CrossRef]
239. Mohanty, A.; Mishra, K.N.; Roul, P.K.; Dash, S.N.; Panigrahi, K.K. Effects of conservation agriculture production system (CAPS) on soil organic carbon, base exchange characteristics and nutrient distribution in a tropical rainfed agro-ecosystem. *Int. J. Plant Anim. Environ. Sci.* **2015**, *5*, 310–314.
240. Zerihun, A.B.; Tadesse, B.; Shiferaw, T.; Kifle, D. Conservation agriculture: Maize-legume intensification for yield, profitability and soil fertility improvement in maize belt areas of western Ethiopia. *Int. J. Plant Soil Sci.* **2014**, *3*, 969–985. [CrossRef]
241. Fonteyne, S.; Burgueño, J.; Albarrán Contreras, B.A.; Andrio Enríquez, E.; Castillo Villaseñor, L.; Enyanche Velázquez, F.; Escobedo Cruz, H.; Espidio Balbuena, J.; Espinosa Solorio, A.; Garcia Meza, P.; et al. Effects of conservation agriculture on physicochemical soil health in 20 maize-based trials in different agro-ecological regions across Mexico. *Land Degrad. Dev.* **2021**, *32*, 2242–2256. [CrossRef]
242. Mrabet, R.; Moussadek, R.; Fadlaoui, A.; van Ranst, E. Conservation agriculture in dry areas of Morocco. *Field Crops Res.* **2012**, *132*, 84–94. [CrossRef]
243. Thomas, G.A.; Dalal, R.C.; Standley, J. No-till effects on organic matter, pH, cation exchange capacity and nutrient distribution in a Luvisol in the semi-arid subtropics. *Soil Tillage Res.* **2007**, *94*, 295–304. [CrossRef]
244. Alam, M.K.; Bell, R.W.; Haque, M.E.; Islam, M.A.; Kader, M.A. Soil nitrogen storage and availability to crops are increased by conservation agriculture practices in rice–based cropping systems in the Eastern Gangetic Plains. *Field Crops Res.* **2020**, *250*, 107764. [CrossRef]
245. Camarotto, C.; Dal Ferro, N.; Piccoli, I.; Polese, R.; Furlan, L.; Chiarini, F.; Morari, F. Conservation agriculture and cover crop practices to regulate water, carbon and nitrogen cycles in the low-lying Venetian plain. *Catena* **2018**, *167*, 236–249. [CrossRef]
246. Haokip, I.C.; Dwivedi, B.S.; Meena, M.C.; Datta, S.P.; Jat, H.S.; Dey, A.; Tigga, P. Effect of conservation agriculture and nutrient management options on soil phosphorus fractions under maize-wheat cropping system. *J. Indian Soc. Soil Sci.* **2020**, *68*, 45–53. [CrossRef]

247. Jat, H.S.; Datta, A.; Sharma, P.C.; Kumar, V.; Yadav, A.K.; Choudhary, M.; Choudhary, V.; Gathala, M.K.; Sharma, D.K.; Jat, M.L.; et al. Assessing soil properties and nutrient availability under conservation agriculture practices in a reclaimed sodic soil in cereal-based systems of North-West India. *Arch. Agron. Soil Sci.* **2018**, *64*, 531–545. [CrossRef] [PubMed]
248. Chan, K.Y.; Roberts, W.P.; Heenan, D.P. Organic carbon and associated properties of a red earth after 10 years rotation under different stubble and tillage practices. *Aust. J. Soil Res.* **1992**, *30*, 71–83. [CrossRef]
249. Sharma, V.; Irmak, S.; Padhi, J. Effects of cover crops on soil quality: Part II. Soil exchangeable bases (potassium, magnesium, sodium, and calcium), cation exchange capacity, and soil micronutrients (zinc, manganese, iron, copper, and boron). *J. Soil Water Conserv.* **2018**, *73*, 652–668. [CrossRef]
250. Kumar, D.; Kumar, S.; Parveen, H.; Priyanka; Kumar, R.; Kumari, D. Effect of establishment techniques and cropping systems on transformation of zinc in alluvial soil under conservation agriculture. *Int. J. Curr. Microbiol. Appl. Sci.* **2020**, *9*, 2585–2594. [CrossRef]
251. Feng, Y.; Liu, Q.; Tan, C.; Yang, G.; Qin, X.; Xiang, Y. Water and nutrient conservation effects of different tillage treatments in sloping fields. *Arid Land Res. Manag.* **2014**, *28*, 14–24. [CrossRef]
252. Govaerts, B.; Sayre, K.D.; Ceballos, R.J.M.; Luna, G.M.L.; Limon, O.A.; Deckers, L.; Dendooven, L. Conventionally tilled and permanent raised beds with different crop residue management: Effects on soil C and N dynamics. *Plant Soil* **2006**, *280*, 143–155. [CrossRef]
253. Sato, S.; Comerford, N.B. Influence of soil pH on inorganic phosphorus sorption and desorption in a humid Brazilian Ultisol. *Rev. Bras. Cienc. Solo* **2005**, *29*, 685–694. [CrossRef]
254. Deubel, A.; Hofmann, B.; Orzessek, D. Long-term effects of tillage on stratification and plant availability of phosphate and potassium in a loess chernozem. *Soil Tillage Res.* **2011**, *117*, 85–92. [CrossRef]
255. Lupwayi, N.Z.; Clayton, G.W.; O'Donovan, J.T.; Harker, K.N.; Turkington, T.K.; Soon, Y.K. Soil nutrient stratification and uptake by wheat after seven years of conventional and zero tillage in the Northern Grain belt of Canada. *Can. J. Soil Sci.* **2006**, *86*, 767–778. [CrossRef]
256. Obour, A.K.; Holman, J.D.; Simon, L.M.; Schlegel, A.J. Strategic tillage effects on crop yields, soil properties, and weeds in dryland no-tillage systems. *Agronomy* **2021**, *11*, 662. [CrossRef]
257. Hu, Z.H.; Ling, H.; Chen, S.T.; Shen, S.H.; Zhang, H.; Sun, Y.Y. Soil respiration, nitrification, and denitrification in a wheat farmland soil under different managements. *Commun. Soil Sci. Plant Anal.* **2013**, *44*, 3092–3102. [CrossRef]
258. Morugán, C.A.; Linares, P.C.; Gómez, L.M.D.; Faz, A.; Zornoza, R. The impact of intercropping, tillage and fertilizer type on soil and crop yield in fruit orchards under Mediterranean conditions: A meta-analysis of field studies. *Agric. Syst.* **2020**, *178*, 102736. [CrossRef]
259. Sujatha, D.V.; Kavitha, P.; Naidu, M.V.S. Influence of green manure and potassium nutrition on soil potassium fractions and yield of rice crop. *Int. J. Curr. Microbiol. Appl. Sci.* **2017**, *6*, 13–23. [CrossRef]
260. Durán, Z.V.H.; Cárceles, B.; García-Tejero, I.F.; Gálvez, R.B.; Cuadros, T.S. Benefits of organic olive rainfed systems to control soil erosion and runoff and improve soil health restoration. *Agron. Sustain. Dev.* **2020**, *40*, 41. [CrossRef]
261. Belay, S.A.; Assefa, T.T.; Prasad, P.V.V.; Schmitter, P.; Worqlul, A.W.; Steenhuis, T.S.; Reyes, M.R.; Tilahun, S.A. The response of water and nutrient dynamics and of crop yield to conservation agriculture in the Ethiopian highlands. *Sustainability* **2020**, *12*, 5989. [CrossRef]
262. Durán, Z.V.H.; Martínez, R.A.; Aguilar, R.J. Nutrient losses by runoff and sediment from the taluses of orchard terraces. *Water Air Soil Pollut.* **2004**, *153*, 355–373. [CrossRef]
263. Issaka, F.; Zhang, Z.; Zhao, Z.Q.; Asenso, E.; Li, J.H.; Li, Y.T.; Wang, J.J. Sustainable conservation tillage improves soil nutrients and reduces nitrogen and phosphorous losses in maize farmland in southern China. *Sustainability* **2019**, *11*, 2397. [CrossRef]
264. Nummer, A.S.; Qian, S.S.; Harmel, D.R. A meta-analysis on the effect of agricultural conservation practices on nutrient loss. *J. Environ. Qual.* **2018**, *47*, 1172–1178. [CrossRef]
265. Smith, D.R.; Francesconi, W.; Livingston, S.J.; Huang, C. Phosphorus losses from monitored fields with conservation practices in the Lake Erie Basin, USA. *Ambio* **2015**, *44*, 319–331. [CrossRef] [PubMed]
266. Jordan, V.W.; Leake, A.R.; Ogilvy, S.E. Agronomic and environmental implications of soil management practices in integrated farming systems. *Asp. Appl. Biol.* **2000**, *62*, 61–66.
267. Liu, Y.; Tao, Y.; Wan, K.; Zhang, G.; Liu, D.; Xiong, G.Y.; Chen, F. Runoff and nutrient losses in citrus orchards on sloping land subjected to different surface mulching practices in the Danjiangkou Reservoir area of China. *Agric. Water Manag.* **2012**, *110*, 34–40. [CrossRef]
268. Liu, R.; Zhang, P.; Wang, X.; Chen, Y.; Zhenyao, S. Assessment of effects of best management practices on agricultural non-point source pollution in Xiangxi River watershed. *Agric. Water Manag.* **2013**, *117*, 9–18. [CrossRef]
269. García-Díaz, A.; Bienes, R.; Sastre, B.; Novara, A.; Gristina, L.; Cerdà, A. Nitrogen losses in vineyards under different types of soil groundcover. A field runoff simulator approach in central Spain. *Agric. Ecosyst. Environ.* **2017**, *236*, 256–267. [CrossRef]
270. Dinnes, D.L.; Karlen, D.L.; Jaynes, D.B.; Kaspar, T.C.; Hatfield, J.L.; Colvin, T.S.; Cambardella, C.A. Nitrogen management strategies to reduce nitrate leaching in tile-drained Midwestern soils. *Agron. J.* **2002**, *94*, 153–171. [CrossRef]
271. Wyland, L.J.; Jackson, L.E.; Chaney, W.E.; Klonsky, K.; Koike, S.T.; Kimple, B. Winter cover crops in a vegetable cropping system: Impacts on nitrate leaching, soil water, crop yield, pests and management costs. *Agric. Ecosyst. Environ.* **1996**, *59*, 1–17. [CrossRef]

272. Colombani, N.; Mastrocicco, M.; Vincenzi, F.; Castaldelli, G. Modeling soil nitrate accumulation and leaching in conventional and conservation agriculture cropping systems. *Water* **2020**, *12*, 1571. [CrossRef]
273. Thiele-Bruhn, S.; Bloem, J.; de Vries, F.T.; Kalbitz, K.; Wagg, C. Linking soil biodiversity and agricultural soil management. *Curr. Opin. Environ. Sustain.* **2012**, *4*, 523–528. [CrossRef]
274. Zornoza, R.; Guerrero, C.; Mataix Solera, J.; Scow, K.M.; Arcenegui, V.; Mataix-Beneyto. J. Changes in soil microbial community structure following the abandonment of agricultural terraces in mountainous areas of Eastern Spain. *Appl. Soil Ecol.* **2009**, *42*, 315–323. [CrossRef]
275. Kabiri, V.; Raiesi, F.; Ghazavi, M.A. Tillage effects on soil microbial biomass, SOM mineralization and enzyme activity in a semi-arid Calcixerepts. *Agric. Ecosyst. Environ.* **2016**, *232*, 73–84. [CrossRef]
276. Haichar, F.; El, Z.; Santaella, C.; Heulin, T.; Achouak, W. Root exudates mediated interactions belowground. *Soil Biol. Biochem.* **2014**, *77*, 69–80. [CrossRef]
277. Lopes, L.D.; Fernandes, M.F. Changes in microbial community structure and physiological profile in a kaolinitic tropical soil under different conservation agricultural practices. *Appl. Soil Ecol.* **2020**, *152*. [CrossRef]
278. Singh, U.; Choudhary, A.K.; Sharma, S. Comparative performance of conservation agriculture vis-a-vis organic and conventional farming, in enhancing plant attributes and rhizospheric bacterial diversity in *Cajanus cajan*: A field study. *Eur. J. Soil Biol.* **2020**, *99*, 103197. [CrossRef]
279. Wang, Z.; Liu, L.; Chen, Q.; Liao, Y. Conservation tillage increases soil bacterial diversity in the dryland of northern China. *Agron. Sustain. Dev.* **2016**, *36*, 28. [CrossRef]
280. Silva, A.P.; Babujia, L.C.; Matsumoto, L.S.; Guimarães, M.F.; Hungria, M. Bacterial diversity under different tillage and crop rotation systems in an oxisol of Southern Brazil. *Open Agric. J.* **2013**, *7*, 40–47. [CrossRef]
281. Dorr de Quadros, P.; Zhalnina, K.; Davis, R.A.; Fagen, J.R.; Drew, J.; Bayer, C.; Camargo, F.A.O.; Triplett, E.W. The effect of tillage system and crop rotation on soil microbial diversity and composition in a subtropical acrisol. *Diversity* **2021**, *4*, 375. [CrossRef]
282. Henneron, L.; Bernard, L.; Hedde, M.; Pelosi, C.; Villenave, C.; Chenu, C.; Bertrand, M.; Girardin, C.; Blanchart, E. Fourteen years of evidence for positive effects of conservation agriculture and organic farming on soil life. *Agron. Sustain. Dev.* **2015**, *35*, 169–181. [CrossRef]
283. Baghel, J.K.; Das, T.K.; Raj, R.; Sangeeta, P.; Mukherjee, I.; Bisht, M. Effect of conservation agriculture and weed management on weeds, soil microbial activity and wheat (*Triticum aestivum*) productivity under a rice (*Oryza sativa*)-wheat cropping system. *Indian J. Agric. Sci.* **2018**, *88*, 1709–1716.
284. Li, Y.; Chang, S.X.; Tian, L.; Zhang, Q. Conservation agriculture practices increase soil microbial biomass carbon and nitrogen in agricultural soils: A global meta-analysis. *Soil Biol. Biochem.* **2018**, *121*, 50–58. [CrossRef]
285. Choudhary, M.; Datta, A.; Jat, H.S.; Yadav, A.K.; Gathala, M.K.; TeSapkota, T.B.; Das, A.K.; Sharma, P.C.; Jat, M.L.; Singh, R.; et al. Changes in soil biology under conservation agriculture based sustainable intensification of cereal systems in Indo-Gangetic Plains. *Geoderma* **2018**, *313*, 193–204. [CrossRef]
286. Kumar, B.T.N.; Babalad, H.B. Soil organic carbon, carbon sequestration, soil microbial biomass carbon and nitrogen and soil enzymatic activity as influenced by conservation agriculture in pigeonpea and soybean intercropping system. *Int. J. Curr. Microbiol. Appl. Sci.* **2018**, *7*, 323–333. [CrossRef]
287. Spedding, T.A.; Hamel, C.; Mehuys, G.R.; Madramootoo, C.A. Soil microbial dynamics in maize-growing soil under different tillage and residue management systems. *Soil Biol. Biochem.* **2004**, *36*, 499–512. [CrossRef]
288. Ceja-Navarro, J.A.; Rivera, F.N.; Patiño-Zúñiga, L.; Govaerts, B.; Marsch, R.; Vila-Sanjurjo, A.; Dendooven, L. Molecular characterization of soil bacterial communities in contrasting zero tillage systems. *Plant Soil* **2010**, *329*, 127–137. [CrossRef]
289. Legrand, F.; Picot, A.; Cobo, D.J.F.; Carof, M.; Chen, W.; Le Floch, G. Effect of tillage and static abiotic soil properties on microbial diversity. *Appl. Soil Ecol.* **2018**, *132*, 135–145. [CrossRef]
290. Mathew, R.P.; Feng, Y.; Githinji, L.; Ankumah, R.; Balkcom, K.S. Impact of no-tillage and conventional tillage systems on soil microbial communities. *Appl. Environ. Soil Sci.* **2012**, *2012*, 548620. [CrossRef]
291. Habig, J.; Swanepoel, C. Effects of conservation agriculture and fertilization on soil microbial diversity and activity. *Environments* **2015**, *2*, 358–384. [CrossRef]
292. Bonini Pires, C.A.; Amado, T.J.C.; Reimche, G.; Schwalbert, R.; Sarto, M.V.M.; Nicoloso, R.S.; Fiorin, J.E.; Rice, C.W. Diversified crop rotation with no-till changes microbial distribution with depth and enhances activity in a subtropical Oxisol. *Eur. J. Soil Sci.* **2020**, *71*, 1173–1187. [CrossRef]
293. Banerjee, T.; Sharma, S.; Thind, H.S.; Yadvinder, S.; Sidhu, H.S.; Jat, M.L. Soil biochemical changes at different wheat growth stages in response to conservation agriculture practices in a rice-wheat system of north-western India. *Soil Res.* **2017**, *56*, 91–104. [CrossRef]
294. Sharma, S.; Vashisht, M.; Singh, Y.; Thind, H.S. Soil carbon pools and enzyme activities in aggregate size fractions after seven years of conservation agriculture in a rice–wheat system. *Crop. Pasture Sci.* **2019**, *70*, 473–485. [CrossRef]
295. Kandeler, E.; Palli, S.; Stemmer, M.; Gerzabek, M.H. Tillage changes microbial biomass and enzyme activities in particle-size fractions of a Haplic Chernozem. *Soil Biol. Biochem.* **1999**, *31*, 1253–1264. [CrossRef]
296. Roldán, A.; Caravaca, F.; Hernández, M.T.; García, C.; Sánchez, B.C.; Velásquez, M.; Tiscareno, M. No-tillage, crop residue additions and legume cover cropping effects on soil quality characteristics under maize in Patzcuaro watershed (Mexico). *Soil Tillage Res.* **2003**, *72*, 65–73. [CrossRef]

297. Pandey, D.; Agrawal, M.; Bohra, J.S. Effects of conventional tillage and no tillage permutations on extracellular soil enzyme activities and microbial biomass under rice cultivation. *Soil Tillage Res.* **2014**, *136*, 51–60. [CrossRef]
298. Sinsabaugh, R.L.; Lauber, C.L.; Weintraub, M.N.; Ahmed, B.; Allison, S.D.; Crenshaw, C.; Contosta, A.R.; Cusack, D.; Frey, S.; Gallo, M.E. Stoichiometry of soil enzyme activity at global scale. *Ecol. Lett.* **2008**, *11*, 1252–1264. [CrossRef]
299. Kooch, Y.; Jalilvand, H. Earthworms as ecosystem engineers and the most important detritivors in forest soils. *Pak. J. Biol Sci.* **2008**, *11*, 819–825. [CrossRef]
300. Chan, K.Y. An overview of some tillage impacts on earthworm population abundance and diversity—Implications for functioning in soils. *Soil Tillage Res.* **2001**, *57*, 179–191. [CrossRef]
301. Capowiez, Y.; Cadoux, S.; Bouchant, P.; Ruy, S.; Roger, E.J.; Richard, G.; Boizard, H. The effect of tillage type and cropping system on earthworm communities, macroporosity and water infiltration. *Soil Tillage Res.* **2009**, *105*, 209–216. [CrossRef]
302. Pelosi, C.; Pey, B.; Hedde, M.; Caro, G.; Capowiez, Y.; Guernion, M.; Peigné, J.; Piron, D.; Bertrand, M.; Cluzeau, D. Reducing tillage in cultivated fields increases earthworm functional diversity. *Appl. Soil Ecol.* **2014**, *83*, 79–87. [CrossRef]
303. Baldivieso-Freitas, P.; Blanco, M.J.M.; Gutiérrez, L.M.; Peigné, J.; Pérez, F.A.; Trigo, A.D.; Sans, F.X. Earthworm abundance response to conservation agriculture practices in organic arable farming under Mediterranean climate. *Pedobiologia* **2018**, *66*, 58–64. [CrossRef]
304. Van Capelle, C.; Schrader, S.; Brunotte, J. Tillage-induced changes in functional diversity of soil biota—A review with a focus on German data. *Eur. J. Soil Biol.* **2012**, *50*, 165–181. [CrossRef]
305. Radford, B.J.; Key, A.J.; Robertson, L.N.; Thomas, G.A. Conservation tillage increases soil water storage, soil animal populations, grain yield and response to fertilizer in the semi-arid tropics. *Aust. J. Exp. Agric.* **1995**, *35*, 223–232. [CrossRef]
306. Birkás, M.; Jolánkai, M.; Gyuricza, C.; Percze, A. Tillage effects on compaction, earthworms and other soil quality indicators in Hungary. *Soil Tillage Res.* **2004**, *78*, 185–196. [CrossRef]
307. Errouissi, F.; Ben Moussa-Machraoui, S.; Ben-Hammouda, M.; Nouira, S. Soil invertebrates in durum wheat (*Triticum durum* L.) cropping system under Mediterranean semi-arid conditions: A comparison between conventional and no-tillage management. *Soil Tillage Res.* **2011**, *112*, 122–132. [CrossRef]
308. Chan, K.Y.; Heenan, D.P. Earthworm population dynamics under conservation tillage systems in southeastern Australia. *Aust. J. Soil Res.* **2006**, *44*, 425–431. [CrossRef]
309. Sharma, S.; Dhaliwal, S.S. Conservation agriculture based practices enhanced micronutrients transformation in earthworm cast soil under rice-wheat cropping system. *Ecol. Eng.* **2021**, *163*, 106195. [CrossRef]
310. Muoni, T.; Mhlanga, B.; Forkman, J.; Sitali, M.; Thierfelder, C. Tillage and crop rotations enhance populations of earthworms, termites, dung beetles and centipedes: Evidence from a long-term trial in Zambia. *J. Agric. Sci.* **2019**, *157*, 504–514. [CrossRef]
311. Bertrand, M.; Barot, S.; Blouin, M.; Whalen, J.; De Oliveira, T.; Roger, E.J. Earthworm services for cropping systems: A review. *Appl. Soil Ecol.* **2014**, *83*, 79–87. [CrossRef]
312. Schmidt, O.; Clements, R.O.; Donaldson, G. Why do cereal-legume intercrops support large earthworm populations? *Appl. Soil Ecol.* **2003**, *22*, 181–190. [CrossRef]
313. Hanson, P.; Edwards, N.; Garten, C.T.; Andrews. J.A. Separating root and soil microbial contributions to soil respiration: A review of methods and observations. *Biogeochemistry* **2001**, *48*, 115–146. [CrossRef]
314. Bondlamberty, B.; Thomson, A. Temperature-associated increases in the global soil respiration record. *Nature* **2010**, *464*, 579–582. [CrossRef]
315. Askari, M.S.; Holden, N.M. Indices for quantitative evaluation of soil quality under grassland management. *Geoderma* **2014**, *230–231*, 131–142. [CrossRef]
316. Xue, H.; Tang, H. Responses of soil respiration to soil management changes in an agropastoral ecotone in Inner Mongolia, China. *Ecol. Evol.* **2018**, *8*, 220–230. [CrossRef]
317. Edralin, D.I.A.; Sigua, G.C.; Reyes, M. Dynamics of Soil Carbon, Nitrogen and Soil Respiration in Farmer's Field with Conservation Agriculture in Cambodia. *Int. J. Plant Sci.* **2016**, *11*, 1–13. [CrossRef]
318. Shi, X.; Zhang, X.; Yang, X.; Drury, C.F.; McLaughlin, N.B.; Liang, A.; Fan, R.; Jia, S. Contribution of winter soil respiration to annual soil CO_2 emission in a Mollisol under different tillage practices in northeast China. *Glob. Biogeochem. Cycles* **2012**, *26*, GB2007. [CrossRef]
319. Cooper, R.J.; Hama-Aziz, Z.Q.; Hiscock, K.M.; Lovett, A.A.; Vrain, E.; Dugdale, S.J.; Sünnenberg, G.; Dockerty, T.; Hovesen, P.; Noble, L. Conservation tillage and soil health: Lessons from a 5-year UK farm trial (2013–2018). *Soil Tillage Res.* **2002**, *202*, 104648. [CrossRef]
320. Ye, R.; Parajuli, B.; Szogi, A.A.; Sigua, G.C.; Ducey, T.F. Soil health assessment after 40 years of conservation and conventional tillage management in Southeastern Coastal Plain soils. *Soil Sci. Soc. Am. J.* **2021**, *85*, 1214–1225. [CrossRef]
321. Rusu, T.; Bogdan, I.; Marin, D.I.; Moraru, P.I.; Pop, A.I.; Duda, B.M. Effect of conservation agriculture on yield and protecting environmental resources. *Agrolife Sci. J.* **2015**, *4*, 141–145.
322. Gyawali, A.J.; Strickland, M.S.; Thomason, W.; Reiter, M.; Stewart, R. Quantifying short-term responsiveness and consistency of soil health parameters in row crop systems: Part 1: Developing a multivariate approach. *Soil Tillage Res.* **2022**, *219*, 105354. [CrossRef]
323. Nunes, M.R.; van Es, H.M.; Schindelbeck, R.; Ristow, A.J.; Ryan, M. No-till and cropping system diversification improve soil health and crop yield. *Geoderma* **2018**, *328*, 30–43. [CrossRef]

324. Demir, Z.; Tursun, N.; Işik, D. Effects of Different Cover Crops on Soil Quality Parameters and Yield in an Apricot Orchard. *Int J. Agric. Biol.* **2018**, *21*, 399–408. [CrossRef]
325. Williams, H.; Colombi, T.; Keller, T. The influence of soil management on soil health: An on-farm study in southern Sweden. *Geoderma* **2020**, *360*, 114010. [CrossRef]
326. Parihar, C.M.; Singh, A.K.; Jat, S.L.; Dey, A.; Nayak, H.S.; Mandal, B.N.; Saharawat, Y.S.; Jat, M.L.; Yadav, O.P. Soil quality and carbon sequestration under conservation agriculture with balanced nutrition in intensive cereal-based system. *Soil Tillage Res.* **2020**, *202*, 104653. [CrossRef]
327. Bera, T.; Sharma, S.; Thind, H.S.; Sidhu, H.S.; Jat, M.L. Changes in soil biochemical indicators at different wheat growth stages under conservation-based sustainable intensification of rice-wheat system. *J. Integr. Agric.* **2018**, *17*, 1871–1880. [CrossRef]