Effects of Straw Mulching and Reduced Tillage on Crop Production and Environment: A Review

Changliang Du 1,2, Lingling Li 1,2,∗ and Zechariah Effah 1,2

1 College of Agronomy, Gansu Agricultural University, Lanzhou 730070, China
2 State Key Laboratory of Aridland Crop Science, Gansu Agricultural University, Lanzhou 730070, China
∗ Correspondence: lill@gsau.edu.cn; Tel.: +86-0931-7631145

Abstract: Taking sustainable agriculture measures is critical to effectively cope with the effect of the increasing population on water shortage. Straw mulching and reduced tillage are the most successful measures adopted in arid and semi-arid regions which affect crop production by changing the crop environment. This review focuses on the effects of tillage and mulching on the soil environment, including soil organic matter, soil moisture, soil temperature, soil microorganisms, soil enzyme activity, soil fertility, soil carbon emissions, pests, weeds, and soil erosion. In addition, water use efficiency and crop production are discussed under different tillage measures. Straw mulching can increase soil organic matter content, adjust soil moisture, and prevent water loss and drought; however, it can also lead to an increase in pests and diseases, and change the structure of the soil microbial community. Straw mulching can significantly enhance WUE (water use effectively) and yield. Reducing tillage maintains soil integrity, which is conducive to soil and water conservation, but could negatively impact crop yield and WUE. Precise field management measures, taken according to crop varieties and local conditions, not only ensure the high yield of crops but also protect the environment.

Keywords: straw mulching; reduced tillage; crop yield; water use efficiency; environment

1. Introduction

The growing population has increased the competition for land, water, and other resources, whilst also raising the demand for food [1,2]. Arid and semi-arid regions account for about half of the world’s total land area [3] and could play a vital role in solving the world’s food security problems [4]. Increasing the yield per unit of grain is an effective measure to ensure food security. As agricultural production from drylands is limited due to the scarcity of rainfall, therefore, it is essential to increase crop productivity and yields by optimizing agricultural field management practices [5].

Adopting appropriate agricultural measures not only improves water use efficiency by minimizing the non-productive water consumption of farmland water but also increases productivity, reduces soil erosion, and improves the ecological environment [6]. Meanwhile, it is also necessary to eliminate the enormous pressure that agriculture occupies environmental resources. It is very important to choose field management measures that not only ensure the stability and high yield of agricultural production but also contribute to the sustainable development of the ecological environment. Therefore, it is vital to discuss the effects of field management measures on the crop yield and soil environment associated with crop plants.

Among different agricultural measures, mulching, tillage, and their combination are considered as most sustainable agricultural practices in arid and semi-arid regions as they retain water in the upper soil layers reducing the need for irrigation [7]. Compared with traditional soil tillage measures, the implementation of mulching and reduced tillage techniques can significantly reduce soil surface water evaporation [8], surface runoff [9,10], and
soil erosion [11], and increase soil water storage. To an extent, it increases crop yield and water use efficiency and guarantees the sustainable development of agriculture [12,13]. Straw mulching has been widely used for the cultivation of maize (Zea mays L.) [14], spring wheat (Triticum aestivum L.) [15], rice (Oryza sativa L.) [16], potatoes (Solanum tuberosum, L) [17], vegetables [18] and fruit trees [19]. This farming method not only guarantees the production of crops [20] but is also extremely friendly to the environment [21].

Straw mulching has many advantages: firstly, it reduces the loss of soil moisture and can be an effective means for improving plant available water [22], which in turn improves WUE and crop production [8,23]. Secondly, it balances the soil temperature [24] and reduces the maximum soil temperature but increases the minimum soil temperature [25]. Thirdly, it affects the soil microbial biomass [26]. Studies have shown that mulching significantly increases microbial biomass [27], but some contrasting studies have shown that conventional tillage can increase soil microbial biomass [28]. Fourth, it can affect the balance of soil organic carbon. A positive correlation has been found between organic residues in soil and soil organic carbon content [29,30]. Fifth, it can promote soil enzyme activity. The enzyme activity and metabolic index of straw mulching treatment were higher than those of conventional tillage [31]. Furthermore, straw mulching can suppress and reduce weed [32], as well as decrease runoff volumes [10].

Long-term tillage can affect soil function and thus crop yield [33]. Therefore, no-tillage or reduced tillage has been adopted in many areas of the world as field management to improve grain yield [33,34]. These measures play an important role in field management to improve grain yield. First, it can improve the level of soil organic matter which might offset the negative impact of residue removal [35,36]. Second, no-tillage or reduced tillage reduces the costs of production, increases soil compaction and bearing capacity, and can also alleviate the damage of wheel pressure [37] and increase area performance [38]. Third, no-tillage or reduced tillage can improve moisture infiltration [39] and enhance water use efficiency [40].

The tillage practices and mulching affect crop growth in slow processes by affecting the soil environment [41]. Thus, to ensure ecological stability and high yield, it is vital to review the effects of these measures on the crop soil environment. However, under field conditions, multiple tillage methods are often adopted. So it is difficult to understand the effects of a single tillage measure. In this review, we will discuss the effects of mulch and no-tillage or reduced tillage on the crop yield and environment.

2. The Effect of Straw Mulching and Reduced Tillage on the Soil Environment

2.1. Soil Organic Matter

Soil organic matter (SOM) plays a vital role in crop production by providing the most basic energy substrate and restoring degraded soils [42]. The decomposition of organic mulching by soil microorganisms produces high content of SOM, increases soil biodiversity, and maintains good ecosystem functions [43]. Proper mulching and irrigation have successfully increased the crop production of some farmlands with initial low soil fertility [44]. A long-term zero tillage with residues incorporation for 11 years showed a significant increase in the SOM and improved aggregate size distribution and stability [45]. Similar studies showed that the SOM increased significantly after straw mulching [46] and alfalfa and bark mulching [47].

Most studies have shown that no-tillage can increase the amount of SOM in the 0–100 cm topsoil [48,49] by reducing soil disturbance, mineralization, and decomposition of organic matter [50]. Baan et al. [51] reported that compared with long-term continuous tillage, a short cycle of single tillage had little effect on soil physiochemical properties. In addition, no or reduced tillage was effective in increasing free unprotected organic matter [52]. Wang et al. (2008) showed a 22% increase in the SOM content in the 0–100 cm soil layer after the long-term no-tillage compared with traditional tillage in the semi-arid Loess Plateau [53]. However, the effect of no-tillage on the SOM content is not well observed in arid and semi-arid agricultural areas showing some contradictory effects because of
the different soil environments and climatic conditions. In general, straw mulching with reduced or no-tillage has significant effects on improving soil organic matter.

2.2. Soil Moisture

Soil moisture directly affects the growth of plants, and reasonable soil moisture is the most important factor in ensuring high quality and high yield of crops. In arid and semi-arid areas, conserving soil moisture and increasing WUE are key to crop production [54]. Straw mulching reduces the evaporation of the soil moisture and water is available to plant roots in the upper soil layer which reduces evapotranspiration loss of underground water by capillary fringe [55]. In arid and semi-arid areas, straw mulching reduces evaporation during years with little rain, increases the movement of soil moisture [56], and improves the soil moisture at the depth of 0–40 cm compared with traditional tillage [57,58]. Similarly, in the Mediterranean environment, straw mulching significantly improved the soil moisture at the depth of 5–15 cm [59]. Several field studies had reported a positive impact of the combined application of no-tillage and reduced tillage on soil moisture which ensures the absorption and utilization of moisture by plants [60]. Furthermore, the straw left on the soil surface can minimize the negative impact of no-tillage on water infiltration [61].

2.3. Soil Temperature

Soil temperature generally refers to the temperature of the soil in the root growth layer and is related to the root growth. Soil temperature is generally affected by weather, soil moisture, topography, and farming conditions. The easiest way to control soil temperature is by changing field management, including mulching and tillage measures. Bare soils generally have higher temperature changes than covered soils due to albedo effects [62]. Covering soil reduces moisture exchange between soil and air, thereby reducing heat flow and exchange between the soil and air [62]. It is generally believed that farmland mulch works as a partial heat barrier that can prevent ultraviolet rays and reduce heat loss.

Most studies have concluded that straw mulching can reduce the surface soil temperature of spring wheat, corn, rice, and other root crops [55]. Straw mulching can decrease the upper limit of soil temperature and lower the maximum soil temperature, straw mulching may balance the soil’s temperature and make it more favorable for plants to grow and thrive [62]. A study showed that crop residue covering significantly reduces the early plant growth temperature of 2–7 °C [63]. Although the no-tillage straw mulch reduces the surface temperature of the soil, it also increases the soil moisture and water use efficiency at the same time, thereby increasing yield [64]. Another study on rice showed that straw mulching significantly reduced the surface temperature when the temperature increased [56]. Similarly, with the use of wheat straw mulching to cover the plots for planting corn, the maximum soil temperature during the corn growing period lowered when the ambient temperature was high, and the soil temperature increased when the ambient temperature was low and promoted corn production [65]. The temperature of the soil surface improved with the thickness of the straw mulch layer. However, the temperature change mainly appears at 0–40 cm depth, and no significant effect was observed in deeper soil layers [66].

The ground temperature is affected by many factors such as climate, region, vegetation type, cover type, and cover time. It can be concluded that straw mulching and no-tillage practices can affect crop production by affecting soil temperature. It can be seen that the systematic study of soil temperature and its influencing factors have an important impact on the in-depth study of plant growth and development.

2.4. Soil Microorganisms

Soil microorganisms play a remarkable role in sustaining soil structure [67,68], humus formation [69], promote the circulation and flow of material energy in the soil [70], and simultaneously affect plant growth [71].
Straw mulching and less or no tillage could improve the soil microorganisms to varying degrees [70]. In a field study in India, Subrahmaniyan et al. [72] found that the numbers of soil bacteria, fungi, and actinomycetes increased by 2%, 12%, and 12%, respectively, under mulch conditions compared to no mulch conditions. Some studies have proven that the straw mulching had significantly increased the soil microbial biomass by 42% [73] and showed a significant increase in microbial biomass in the 1–9 cm soil layer [74]. However, some studies have proven that mulching has no significant effect on soil microorganisms [75]. Wang et al. have also proven that soil with no mulching has more microbial biomass [76].

Less or no tillage could define the microbial biomass indirectly by affecting soil moisture and temperature [77]. In the no-till system, the activity and quantity of soil microorganisms were significantly higher than those of the tillage soil, and the soil quality parameters of the topsoil microorganisms and the tillage frequency were negatively correlated [78].

Long-term less or no-till combined with straw mulching is more conducive to increasing soil microbial biomass [79]. Reducing soil tillage combined with straw mulching can increase the total amount of bacteria in the topsoil and increase the diversity of soil microorganisms [80]. Studies have shown a more beneficial rhizosphere microbial community under no-tillage which in turn increases crop growth and yield [81]. Some researchers reported no significant change in microbial biomass under no-tillage soil with other treatments [82]. However, the soil microbial biomass and activity is a complex topic that could be affected by the mulch composition and tillage depth determination [83].

2.5. Soil Enzymes

The transformation of soil nutrients and their absorption and utilization by plants is affected by soil enzymes [84]. Soil enzymes are important indicators in measuring soil nutrient status and nutrient cycling [85]. Straw mulching has been shown to improve soil enzymatic activity [86]. One study showed that the soil enzyme activities were significantly improved after 4 years of wheat straw mulching, compared with other treatments [86]. Meanwhile, a study showed that the soil enzyme activity was significantly correlated with the degree of compaction after straw mulching [87]. Straw mulching had shown a significant increase in the activities of protease, urease, sucrose, and alkaline phosphatase during rice and wheat cultivation [88] and white clover and yellow peas cultivation [89]. Crop residue mulch could improve Arylamidase activity compared to bare plots [90]. However, no significant difference was found in the activities of acid phosphatase, protease, and aryl sulfatase after red clover mulching [91].

Soil enzyme activities were also found closely related to the tillage system. This might be because tillage practices can affect the stratified distribution of soil organic matter, thereby affecting the growth of soil microorganisms, which in turn affects the activity of soil enzymes [92] and soil nutrient content [93]. The enzyme activity of the subsoiling mulching treatment was higher than the no-till mulching treatment [94]. Some researchers have also shown that the different physical and chemical properties of soil from different places could affect the distribution and activity of soil enzymes [95].

2.6. Soil Fertility

Straw mulching and tillage either indirectly or directly improve soil fertility. Studies have shown that straw mulching not only increases soil temperature and moisture but also improves soil microbial biomass and nutrient cycling, thereby increasing the content of rhizosphere mineral nitrogen [96]. Straw mulching is itself a source of organic C and SOM which increase the availability of soil nutrients to plants and microbes [97]. Furthermore, it increased the soil’s inorganic nitrogen and microbial carbon and nitrogen content [98] and improved soil physicochemical properties [99]. In shaded coffee agroecosystems, single mulching significantly increased C and N in the soil depth of 0–20 cm compared with no mulching [43]. The study also found that mulching significantly increased soil
exchangeable potassium and phosphorus compared to traditional rice-wheat cropping systems [100]. However, some researchers have reported no clear relationship between soil fertility and straw mulching [101]. No studies have reported the direct positive impact of land tillage practices on soil fertility; however, the combination of straw mulching and tillage practices significantly affects soil fertility.

2.7. Soil Emissions

In recent years, the interest of researchers has rapidly increased in evaluating the effects of different agroecosystems on \(N_2O\) emissions. By comparing the mulching with the non-mulched treatment, it was found that the mulching could effectively reduce the \(N_2O\) emission [102–104]. Similar studies also showed that the average \(N_2O\) emissions from the uncovered treatments were higher than those of the covered treatments in the vicinity of the North Pacific [105]. However, some studies have also shown that surface mulching significantly enhances [106] or has no effect [107] on \(N_2O\) emissions.

Compared with the tillage measures, no-tillage can reduce the concentration of soil electron receptors in paddy fields and inhibit \(N_2O\) and \(CH_4\) emissions [108]. No-tillage can usually increase soil bulk density and reduce soil porosity, resulting in lower emissions [109], but the amount of emission reduction varies due to differences in soil properties [87]. Low soil soluble organic and carbon content [110] and low soil temperature [111] under no-till may also be responsible for reducing emissions in the field. Van Kessel et al. [112] have shown that long-term (more than 10 years) conservation tillage can reduce \(N_2O\) emissions in arid environments because of the better soil structure. However, other studies have also shown that no-till and conventional farming have no significant effects on soil emissions [113]. Some researchers believe that the anaerobic environment of no-till soil can promote denitrification, resulting in higher N leaching [114,115].

2.8. Insect Pests, Weeds, and Soil Erosion

Straw mulching has also been shown to play an important role in the distribution of pests in cultivation. For example, straw mulching increases insect abundance [68,116], meanwhile, it could decrease the insect damage in buckwheat and cabbage [117]. In shaded cannabis, sorghum, and sudangrass non-covered fields, the numbers of Formicidae, Orthoptera, and Phyllanthus were significantly higher than in covered fields [118]. It has been proven that straw mulching significantly changes the disease and pest spectrum [118,119]. Some studies believe that reducing tillage increases the bulk density of the topsoil and reduces the porosity of the soil, resulting in excessive soil nutrient enrichment on the surface aggravating pests and insect pests [120]. Studies have shown that straw mulching can reduce the population of Myzus persicae (Aphididae) on kale (Brassicaceae) plants [118]. Generally, straw mulching controls weed growth by limiting resources [121], especially straw mulching can significantly inhibit the growth of weeds [122]. The weed biomass was significantly lower in covered plots compared to bare plots [123], which was significantly reduced by straw mulch [124]. However, some studies have shown that straw mulching has no significant effect on aboveground biomass and weed numbers [125].

Mulching effectively controls soil erosion, especially in rain-fed areas [126]. Mulching techniques can increase soil moisture to stabilize topsoil and reduce wind erosion during periods of high evaporative capacity [127]. Mulching could reduce soil erosion by increasing infiltration [128], reducing the impact of raindrops [129], reducing runoff velocity [9], improving soil structure and porosity [130], and improving topsoil biodiversity [131]. No-tillage or reduced tillage measures can reduce soil erosion and nutrient loss [132], thereby preventing soil erosion [133]. Above all, the effect of straw mulching and tillage management on the soil environment is shown in Figure 1.
tillage or reduced tillage measures can reduce soil erosion and nutrient loss [132], thereby preventing soil erosion [133]. Above all, the effect of straw mulching and tillage management on the soil environment is shown in Figure 1.

Figure 1. Effects of straw mulching and reduced tillage on the soil environment. The + sign showed a positive effect, the − sign showed the negative effect, and ? indicate the undefined effect.

3. Effects of Straw Mulching and Reduced Tillage on Crop Growth, Grain Yield, and WUE

3.1. Water Use Efficiency

Water use efficiency (WUE) usually refers to the ratio of grain yield or crop biomass to water consumption, which can reflect the growth and production of crops per unit of water consumed [134]. Straw mulching increases crop yield and water use efficiency. According to some articles, compared with conventional tillage, straw mulching can improve water use efficiency by 9–60% [135]. This may be because straw mulching can effectively inhibit the evaporation of soil water and increase the water available for the transpiration of crops [136]. Mulching increases the collection of natural water, which was transported through capillaries to low-lying areas for better uptake by crops [137–139]. Wang et al. [140] collected 1406 WUE values of straw mulching and no mulching field treatments and found that the water use efficiency of crops under mulching treatment was higher than that of no mulching treatment, among which wheat was the most prominent (Table 1).

Table 1. Effects of straw mulching and no-mulching with nitrogen application rate on water use efficiency. Adapted with permission from Ref. [140]. 2019, Wang, X.

|                  | Mulching         | No-Mulching       |
|------------------|------------------|-------------------|
| Rice             | $y = 0.035x + 5.0969$ | $R^2 = 0.4863$   | $y = 0.0318x + 4.924$ | $R^2 = 0.2788$ |
| Maize            | $y = 0.0489x + 5.2747$ | $R^2 = 0.4304$   | $y = 0.0557x + 5.0969$ | $R^2 = 7.0112$ |
| Wheat            | $y = 0.0635x + 2.8018$ | $R^2 = 0.6877$   | $y = 0.0352x + 6.2532$ | $R^2 = 0.4121$ |

Studies have shown that no-tillage measures can effectively improve the water use efficiency of crops, especially under drought conditions [141]. Multiple studies in the Mediterranean region have concluded that no-till and low tillage not only increase soil moisture but also improve water use efficiency [142]. Other studies have also proved that
less tillage preserves more water in the topsoil layer compared to traditional farming [143]. However, contradictory studies reported that crop growth is more efficient in dry farming and deep tillage than in no-tillage implemented for several years [144]. In addition, some other studies show that the conservation tillage methods, such as no-tillage, do not affect soil water retention, WUE, or crop yield compared to traditional farming [145].

### 3.2. Grain Yield

Mulching can effectively change the growing environment of crops, by capturing and utilizing rainfall, which is effective in reducing the risk of crop failure in the field especially in arid or semi-arid regions [29,103]. For example, mulching can effectively increase soil organic matter content, reduce soil moisture evaporation, and improve soil temperature. Grain yield was higher under mulch than on bare land due to the significant effect of mulch in retaining soil moisture and increasing nutrient availability and transfer [146]. Compared with conventional tillage, the application of wheat straw mulch can improve maize yield and economic benefits [104]. Wang et al. [140], reported the effect of mulching on the yield data of 1516 samples of corn, wheat, and rice and showed that the average grain yield of the mulched treatment was higher than that of the no-mulched treatment to varying degrees (Table 2).

|       | Mulching                  | No-Mulching              |
|-------|---------------------------|--------------------------|
| Rice  | $y = 14.598x + 5437.9$   | $y = 13.585x + 4964.8$   |
|       | $R^2 = 0.4729$           | $R^2 = 0.4152$           |
| Maize | $y = 19.313x + 4481.6$   | $y = 18.736x + 3221.9$   |
|       | $R^2 = 0.5481$           | $R^2 = 0.5019$           |
| Wheat | $y = 15.334x + 2198.3$   | $y = 11.34x + 2514.2$    |
|       | $R^2 = 0.4278$           | $R^2 = 0.3435$           |

However, different crops have different requirements for the soil temperature at different growth stages. Studies by some researchers have shown that the increase in soil temperature in the early stage of the crop caused by mulching promotes growth and development [147]. However, it has been reported that an increase in soil temperature in the later stages of growth can accelerate crop senescence and reduce crop dry matter accumulation, thereby reducing crop yield [148]. Some studies also showed that mulching and reduce tillage reduce onion yield and quality [149]. Similarly, in the arid and semi-arid regions of the Loess Plateau in Northwest China, the application of straw mulch is limited because straw mulching reduces soil surface temperature, resulting in decreased grain yields [140]. In low-lying and poorly drained fields, straw mulching can prevent rainfall from being drained in time, causing waterlogging and reducing yields [20].

Arvidsson et al. [150] found that no-till treatment of winter wheat yields was on average lower by 9.5% than that of tillage, probably because long-term no-till increases soil bulk density, hindering moisture connections and root growth between soil layers at different depths [151]. Studies have found that under drought conditions, no-tillage is conducive to the development of wheat [152]. Other studies have also shown that no-tillage can effectively improve the soil environment, resulting in improved yields [34,36]. No mulching and fewer tillage practices can also increase WUE and crop yields [153]. Ashworth et al. [154] studied the effects of no-till and conventional tillage on wheat yields, and their study showed that under no-tillage, higher yields were achieved compared to conventional tillage [50]. Long-term studies have shown that the continuous use of no-till varies greatly over different years [155]. Neugschwandtner et al. [156] reported that no-tillage corn yields were lower than conventionally cultivated maize in the first three years investigated; however, after three years the yields under no-tillage exceeded those of conventional ploughing. The increase in yield was significantly higher in the dry years than in the wet years [157]. After implementing no-till, positive soil promoting factors are expected to increase over time [158]. Analysis by Van Ittersum et al. [159] showed that...
the initial application of no-tillage may have negative results at the start but long-term no-tillage has potential benefits such as reduced fertilizer demand and stable crop yields. The high yield of crops depends on high-quality soil biological and physicochemical properties. Especially in arid and semi-arid regions, straw mulching and no-tillage can ensure a good soil environment for crop growth, thus ensuring the sustainability of crop production.

4. Suggestions for Future Research

It is undeniable fact that less tillage, no-tillage, and straw mulching play an important role in agricultural production, especially in arid and semi-arid regions. These mainly include increasing soil organic matter, improving soil water temperature, reducing surface water evaporation, changing soil microbial structure, promoting soil enzyme activity, and inhibiting weed growth. In addition, crop straw mulching increases the collection and utilization of water, which is conducive to the prevention and control of soil erosion. At this stage, the problem of global warming is becoming more and more serious, resulting in climate change, which directly or indirectly affects agricultural production. The goal of agricultural success is sustainable development, protecting the environment as much as possible while maintaining agricultural field productivity, especially rain-fed agriculture in arid and semi-arid regions. In this direction, there will be a large number of topics to be researched in the future, but the main tasks we are currently facing are as follows.

4.1. Select a Combination of Agricultural Practices

In many parts of the world, especially in rain-fed farming regions, smallholder farmers make up the majority of the population, and it is a realistic requirement for them to develop low-cost input, easy-to-operate, high-efficiency tillage measures. These include tillage, mulching, and fertilization. The combined application of various planting measures can ensure agricultural production and at the same time take good care of the environment; however, the optimal planting measures which are suitable for different regions in the world, including the optimal amount of fertilization, mulching materials, and tillage depth need further research.

4.2. Explore the Role of Trace Elements

Trace elements play a key role in maintaining crop growth. Some researchers believe that the trace elements enriched in crops are closely related to the planting environment. However, the specific mechanism of trace elements in plants and mulching or tillage is still unclear. Therefore, studying the relationship between plant trace elements and the environment is of great significance for us to better ensure food safety and environmental health.

4.3. Application of Plant Physiology in Agriculture

Various hormones and metabolites in plants play a vital role in plant growth. In crop plants, for example, when drought occurs, the roots send hormonal signals to the leaves, causing the stomata to close. This root-induced signal often helps reduce water loss, allowing photosynthesis to continue, thereby increasing water use efficiency. However, at this stage, the research in the direction of plant physiology is mainly carried out in the laboratory, which is separated from the actual agricultural production in the field. In field agriculture, the mechanism of plant physiology and biochemistry needs to be further studied, which is of great significance to study the crop growth.

4.4. Risk of Soil Pollution

No-tillage can cause soil compaction and insufficient soil fertility. At the same time, inappropriate straw mulching may increase the risk of pathogenic microorganisms and pest. Therefore, the maximum coverage area under straw mulching should be carefully investigated in combination with materials such as bio-based polymers and biodegradable polymers. Minimizing the use of pesticides minimizes their potential impact on the environment. Therefore, future research can access their impact on the environment.
5. Conclusions

Two common tillage measures i.e., straw mulching and tillage reduction in arid and semi-arid regions have an impact on the environment, including soil temperature and humidity, microorganisms, enzyme activities, soil erosion, and greenhouse gas emissions, as well as crop growth, production and water use efficiency. Straw mulching creates a physical barrier between the surface and the atmosphere and can significantly improve soil moisture evaporation and soil erosion, regulate soil temperature, and promote plant growth. Tillage measures have a certain impact on soil structure, and different tillage measures in different regions can promote agricultural production. In addition, straw mulching and reduced tillage directly affect the microenvironment of soil microorganisms, changing the sustainability of the environment. The rational utilization of tillage practices is an important challenge for crop production and requires more detailed studies to properly utilize resources under different environments and soil conditions.

Author Contributions: Conceptualization, L.L.; software, validation, L.L., C.D. and Z.E.; investigation, L.L.; resources, L.L.; data curation, C.D.; writing—original draft preparation, C.D.; writing—review and editing, L.L.; supervision, L.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Natural Science Foundation of China (31761143004); Education Science and Technology Innovation Project of Gansu Province (GSSYLMX-02).

Institutional Review Board Statement: All patients involved in this study gave their informed consent. Institutional review board approval of our hospital was obtained for this study.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors have no competing interests that might be perceived to influence the results and discussion reported in this paper.

References

1. Godfray, H.C.J.; Beddington, J.R.; Crute, I.R.; Haddad, L.; Lawrence, D.; Muir, J.F.; Pretty, J.; Robinson, S.; Thomas, S.M.; Toulmin, C. Food Security: The Challenge of Feeding 9 Billion People. Science 2010, 327, 812–818. [CrossRef] [PubMed]

2. Tilman, D.; Balzer, C.; Beufort, H.B.L. Global food demand and the sustainable intensification of agriculture. Proc. Natl. Acad. Sci. USA 2011, 108, 20260–20264. [CrossRef] [PubMed]

3. Wheeler, T.; Von Braun, J. Climate change impacts on global food security. Science 2013, 341, 508–513. [CrossRef] [PubMed]

4. Zampieri, M.; Ceglar, A.; Dentener, F.; Toreti, A. Wheat yield loss attributable to heat waves, drought and water excess at the global, national and subnational scales. Environ. Res. Lett. 2017, 12, 064008. [CrossRef]

5. Sinclair, T.R.; Cassman, K.G. Green revolution still too green. Nature 1999, 398, 556. [CrossRef]

6. Franzluebbers, A.J. Water infiltration and soil structure related to organic matter and its stratification with depth. Soil Tillage Res. 2002, 66, 197–205. [CrossRef]

7. Rasmussen, K.J. Impact of ploughless soil tillage on yield and soil quality: A Scandinavian review. Soil Tillage Res. 1999, 53, 3–14. [CrossRef]

8. Awe, G.O.; Reichert, J.M.; Timm, L.C.; Wendroth, O.O. Temporal processes of soil water status in a sugarcane field under residue management. Plant Soil 2015, 387, 395–411. [CrossRef]

9. Smets, T.; Poesen, J.; Knapsen, A. Spatial scale effects on the effectiveness of organic mulches in reducing soil erosion by water. Earth Sci. Rev. 2008, 89, 1–12. [CrossRef]

10. Wang, J.; Huang, J.; Zhao, X.; Wu, P.; Horwath, W.R.; Li, H.; Jing, Z.; Chen, X. Simulated study on effects of ground managements on soil water and available nutrients in jujube orchards. Land Degrad. Dev. 2016, 27, 35–42. [CrossRef]

11. Luna, L.; Miralles, I.; Andreouelli, M.C.; Gispert, M.; Pellegrini, S.; Vignozzi, N.; Solé-Benet, A. Restoration techniques affect soil organic carbon, glomalin and aggregate stability in degraded soils of a semiarid Mediterranean region. Catena 2016, 143, 256–264. [CrossRef]

12. Gibbon, D. 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; p. 112. ISBN 978-92-5-106871-7. [CrossRef]

13. Hobbs, P.R.; Sayre, K.; Gupta, R. The role of conservation agriculture in sustainable agriculture. Philos. Trans. R. Soc. B Biol. Sci. 2008, 363, 543–555. [CrossRef] [PubMed]

14. Alliaume, F.; Rossing, W.A.H.; Tittonell, P.; Dogliotti, S. Modelling soil tillage and mulching effects on soil water dynamics in raised-bed vegetable rotations. Eur. J. Agron. 2017, 82, 268–281. [CrossRef]
15. Kaur, A.; Brar, A.S. Influence of mulching and irrigation scheduling on productivity and water use of turmeric (Curcuma longa L.) in north-western India. *Irrig. Sci.* 2016, 34, 261–269. [CrossRef]

16. Kim, G.W.; Das, S.; Hwang, H.Y.; Kim, P.J. Nitrous oxide emissions from soils amended by cover-crops and under plastic film mulching: Fluxes, emission factors and yield-scaled emissions. *Atmos. Environ.* 2017, 152, 377–388. [CrossRef]

17. Kurothe, R.S.; Kumar, G.; Singh, R.; Singh, H.B.; Tiwari, S.P.; Vishwakarma, A.K.; Sena, D.R.; Fande, V.C. Effect of tillage and cropping systems on runoff, soil loss and crop yields under semiarid rained agriculture in India. *Soil Tillage Res.* 2014, 140, 126–134. [CrossRef]

18. Zhao, Y.; Li, Y.; Wang, J.; Pang, H.; Li, Y. Buried straw layer plus plastic mulching reduces soil salinity and increases sunflower yield in saline soils. *Soil Tillage Res.* 2016, 155, 363–370. [CrossRef]

19. Zhu, Y.; Lv, G.C.; Chen, Y.L.; Gong, X.F.; Peng, Y.N.; Wang, Z.Y.; Ren, A.T.; Xiong, Y.C. Inoculation of arbuscular mycorrhizal fungi with plastic mulching in rained wheat: A promising farming strategy. *Field Crops Res.* 2017, 204, 229–241. [CrossRef]

20. Miller, K.E.; Witter, E.; Corbeels, M.; Tittonell, P. Conservation agriculture and smallholder farming in Africa: The heretics’ view. *Field Crops Res.* 2009, 114, 23–34. [CrossRef]

21. Knowler, D.; Bradshaw, B. Farmers’ adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy* 2007, 32, 25–48. [CrossRef]

22. Arshad, M.A.; Franzluebbers, A.J.; Azooz, R.H. Components of surface soil structure under conventional and no-tillage in northwestern Canada. *Soil Tillage Res.* 1999, 53, 41–47. [CrossRef]

23. Xie, Z.K.; Wang, Y.J.; Li, F.M. Effect of plastic mulching on soil water use and spring wheat yield in arid region of northwest China. *Agric. Water Manag.* 2005, 75, 71–83. [CrossRef]

24. Zhang, S.; Lövåhl, L.; Grip, H.; Tong, Y.; Yang, X.; Wang, Q. Effects of mulching and catch cropping on soil temperature, soil moisture and wheat yield on the Loess Plateau of China. *Soil Tillage Res.* 2009, 102, 78–86. [CrossRef]

25. Chen, S.; Zhang, X.; Pei, D.; Sun, H.; 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]

26. Balota, E.L.; Yada, I.F.; Amaral, H.; Nakatani, A.S.; Dick, R.P.; Coyne, M.S. Long-term land use influences soil microbial biomass p and s, phosphatase and arylsulfatase activities, and s mineralization in a brazilian oxisol. *Land Degrad. Dev.* 2014, 25, 397–406. [CrossRef]

27. Qiu, Y.; Wang, Y.; Xie, Z. Long-term gravel–sand mulch affects soil physicochemical properties, microbial biomass and enzyme activities in the semi-arid Loess Plateau of North-western China. *Acta Agric. Scand. Sect. B Soil Plant Sci.* 2014, 64, 294–303. [CrossRef]

28. Guo, D.; Li, X.; Li, X.; Wang, J.; Fu, H. Conventional tillage increases soil microbial biomass and activity in the Loess Plateau, China. *Acta Agric. Scand. Sect. B Soil Plant Sci.* 2013, 63, 489–496. [CrossRef]

29. Bationo, A.; Kihara, J.; Vanlauwe, B.; Waswa, B.; Kimetu, J. Soil organic carbon dynamics, functions and management in West African agro-ecosystems. *Agric. Syst.* 2004, 84, 13–25. [CrossRef]

30. Wang, Y.; Li, X.; Fu, T.; Wang, L.; Turner, N.; Siddique, K.; Li, F. Multi-site assessment of the effects of plastic-film mulch on the soil organic carbon balance in semi-arid areas of China. *Agric. For. Meteorol.* 2016, 228–229, 42–51. [CrossRef]

31. Masciandaro, G.; Cecchini, B.; Benedicto, S.; Lee, H.C.; Cook, H.F. Enzyme activity and C and N pools in soil following application of mulches. *Can. J. Soil Sci.* 2004, 84, 39–48. [CrossRef]

32. Campiglia, E.; Radicetti, E.; Mancinelli, R. Cover crops and mulches influence weed management and weed flora composition in strip-tilled tomato (*Solanum lycopersicum*). *Weed Res.* 2015, 55, 416–425. [CrossRef]

33. Ziadi, N.; Angers, D.A.; Gagnon, B.; Lalanne, R.; Morel, C.; Rozet, P.; Chantigny, M.H. Long-term tillage and synthetic fertilization affect soil functioning and crop yields in a corn–soybean rotation in eastern Canada. *Can. J. Soil Sci.* 2014, 94, 365–376. [CrossRef]

34. Lund, M.G.; Carter, P.R.; Oplinger, E.S. Tillage and Crop Rotation Affect Corn, Soybean, and Winter Wheat Yields. *J. Prod. Agric.* 1993, 6, 207. [CrossRef]

35. Saffigna, P.G.; Powellson, D.S.; Brookes, P.C.; Thomas, G.A. Influence of sorghum residues and tillage on soil organic matter and soil microbial biomass in an Australian vertisol. *Soil Biol. Biochem.* 1989, 21, 759–765. [CrossRef]

36. Halvorson, A.D.; Wienhold, B.J.; Black, A.L. Tillage, Nitrogen, and Cropping System Effects on Soil Carbon Sequestration. *Soil Sci. Soc. Am. J.* 2002, 66, 906–912. [CrossRef]

37. Jabro, J.D.; Sainju, U.M.; Stevens, W.B.; Lenssen, A.W.; Evans, R.G. Long-term tillage influences on soil physical properties under dryland conditions in northeastern Montana. *Arch. Agron. Soil Sci.* 2009, 55, 633–647. [CrossRef]

38. Cocci, A.I. Tillage system effects on input efficiency of winter wheat, maize and soybean in rotation. *Rom. Agric. Res.* 2010, 27, 81–87.

39. Shaver, T.M.; Peterson, G.A.; Ahuja, L.R.; Westfall, D.G.; Sherrod, L.A.; Dunn, G. Surface Soil Physical Properties after Twelve Years of Dryland No-Till Management. *Soil Sci. Soc. Am. J.* 2010, 66, 1296–1303. [CrossRef]

40. Hardeman, W.; Johnston, M.; Johnston, D.; Bonetti, D.; Kinmonth, A.L. Application of the Theory of Planned Behaviour in Behaviour Change Interventions: A Systematic Review. *Psychol. Health* 2002, 17, 123–158. [CrossRef]
42. Guimarães, D.V.; Gonzaga, M.I.S.; da Silva, T.O.; da Silva, T.L.; da Silva Dias, N.; Matias, M.I.S. Soil organic matter pools and carbon fractions in soil under different land uses. *Soil Tillage Res.* 2013, 126, 177–182. [CrossRef]

43. Youkhana, A.; Idol, T. Tree pruning mulch increases soil C and N in a shaded coffee agroecosystem in Hawaii. *Soil Biol. Biochem.* 2009, 41, 2527–2534. [CrossRef]

44. Chen, Q.; Liu, Z.; Zhou, J.; Xu, X.; Zhu, Y. Long-term straw mulching with nitrogen fertilization increases nutrient and microbial determinants of soil quality in a maize–wheat rotation on China’s Loess Plateau. *Sci. Total Environ.* 2021, 775, 149590. [CrossRef]

45. Govaerts, B.; Sayre, K.D.; Deckers, J. A minimum data set for soil quality assessment of wheat and maize cropping in the highlands of Mexico. *Soil Tillage Res.* 2006, 87, 163–174. [CrossRef]

46. Zhang, Z.; Qiang, H.; McHugh, A.D.; He, J.; Li, H.; Wang, Q.; Lu, Z. Effect of conservation farming practices on soil organic matter and stratification in a monocropping system of Northern China. *Soil Tillage Res.* 2016, 156, 173–181. [CrossRef]

47. Neilsen, G.; Forge, T.; Angers, D.; Neilsen, D.; Hogue, E. Suitable orchard floor management strategies in organic apple orchards that augment soil organic matter and maintain tree performance. *Plant Soil* 2014, 378, 325–335. [CrossRef]

48. Malhi, S.S.; Kutcher, H.R. Small grains stubble burning and tillage effects on soil organic C and N, and aggregation in northeastern Saskatchewan. *Soil Tillage Res.* 2007, 94, 353–361. [CrossRef]

49. Tan, Z.; Lal, R.; Owens, L.; Izaurralde, R. Distribution of light and heavy fractions of soil organic carbon as related to land use and tillage practice. *Soil Tillage Res.* 2007, 97, 53–59. [CrossRef]

50. Jacobs, A.; Evans, R.S.; Allison, J.; Garner, E.; McCulley, R. Cover crops and no-tillage reduce crop production costs and soil loss, compensating for lack of short-term soil quality improvement in a maize and soybean production system. *Soil Tillage Res.* 2022, 218, 105310. [CrossRef]

51. Baan, C.D.; Grevers, M.C.J.; Schoenau, J. Effects of a single cycle of tillage on long-term no-till prairie soils. *Can. J. Soil Sci.* 2009, 89, 521–530. [CrossRef]

52. Kader, M.A.; Sleutel, S.; D’Haene, K.; De Neve, S. Limited influence of tillage management on organic matter fractions in the surface layer of silt soils under cereal–root crop rotations. *Soil Res.* 2010, 48, 16–26. [CrossRef]

53. Wang, Q.; Bai, Y.; Gao, H.; He, J.; Chen, H.; Chesney, R.C.; Kuhn, N.J.; Li, H. Soil chemical properties and microbial biomass after 16 years of no-tillage farming on the Loess Plateau, China. *Geoderma* 2008, 144, 502–508. [CrossRef]

54. Turner, N.C. Sustainable production of crops and pastures under drought in a Mediterranean environment. *Ann. Appl. Biol.* 2004, 144, 139–147. [CrossRef]

55. Deng, X.P.; Shan, L.; Zhang, H.; Turner, N.C. Improving agricultural water use efficiency in arid and semiarid areas of China. *Agric. Water Manag.* 2006, 80, 23–40. [CrossRef]

56. Adams, J.E. Influence of mulches on runoff, erosion, and soil moisture depletion. *Soil Sci. Soc. Am. J.* 1966, 30, 110–114. [CrossRef]

57. Li, X.; Simunek, J.; Shi, H.; Yan, J.; Peng, Z.; Gong, X. Spatial distribution of soil water, soil temperature, and plant roots in a drip-irrigated intercropping field with plastic mulch. *Eur. J. Agron.* 2017, 83, 47–56. [CrossRef]

58. Zhao, Y.; Pang, H.; Wang, J.; Huo, L.; Li, Y. Effects of straw mulch and buried straw on soil moisture and salinity in relation to sunflower growth and yield. *Field Crops Res.* 2014, 161, 16–25. [CrossRef]

59. Stagnari, F.; Galieni, A.; Speca, S.; Cafiero, G.; Pisante, M. Effects of straw mulching and plant revegetation in an abandoned artificial pasture in Northeast China. *J. Zhejiang Univ. Sci. B* 2014, 15, 163–174. [CrossRef]

60. Wang, H.; Lemke, R.; Goddard, T.; Sprout, C. Tillage and root heat stress in wheat in central Alberta. *Soil Tillage Res.* 2003, 75, 81–90. [CrossRef]

61. Lampurlanes, J.; Cantero-Martínez, C. Hydraulic conductivity, residue cover and soil surface roughness under different tillage systems in semiarid conditions. *Soil Tillage Res.* 2006, 85, 13–26. [CrossRef]

62. Gan, Y.; Siddique, K.H.; Turner, N.C.; Li, X.-G.; Niu, J.-Y.; Yang, C.; Liu, L.; Chai, Q. Ridge-furrow mulching systems—An innovative technique for boosting crop productivity in semiarid rain-fed environments. *Adv. Agron.* 2013, 118, 429–476. [CrossRef]

63. Olasantan, F.O. Effect of time of mulching on soil temperature and moisture regime and emergence, growth and yield of white yam in western Nigeria. *Soil Tillage Res.* 1999, 50, 215–221. [CrossRef]

64. Ratan, S.; Sharma, A.; Dhyani, S.; Dube, R. Tillage and mulching effects on performance of maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system under varying land slopes. *Indian J. Agric. Sci.* 2011, 81, 330–335. [CrossRef]

65. Cadavid, L.F.; El-Sharkawy, M.A.; Costa, A.A.; Sánchez, T. Long-term effects of mulch, fertilization and tillage on cassava grown in sandy soils in northern Colombia. *Field Crops Res.* 1998, 57, 45–56. [CrossRef]

66. Cadavid, L.F.; El-Sharkawy, M.A.; Costa, A.A.; Sánchez, T. Long-term effects of mulch, fertilization and tillage on cassava grown in sandy soils in northern Colombia. *Field Crops Res.* 1998, 57, 45–56. [CrossRef]

67. Yang, Y.M.; Li, W.Q. Effect of different mulch materials on winter wheat production in desalinized soil in Heilongjiang region of North China. *J. Zhejiang Univ. Sci. B* 2006, 7, 858. [CrossRef]

68. Liu, G.; Bai, Z.; Shah, F.; Cui, G.; Xiao, Z.; Gong, H.; Li, D.; Lin, Y.; Li, B.; Ji, G. Compositional and structural changes in soil microbial communities in response to straw mulching and plant revegetation in an abandoned artificial pasture in Northeast China. *Glob. Ecol. Conserv.* 2021, 31, e01871. [CrossRef]

69. Ma, Z.; Zhang, X.; Zheng, B.; Yue, S.; Zhang, X.; Zhai, B.; Wang, Z.; Zheng, W.; Li, Z.; Zamanian, K. Effects of plastic and straw mulching on soil microbial P limitations in maize fields: Dependency on soil organic carbon demonstrated by ecoenzymatic stoichiometry. *Geoderma* 2021, 388, 114928. [CrossRef]

70. Yao, X.H.; Min, H.; Lü, Z.; Yuan, H.P. Influence of acetamiprid on soil enzymatic activities and respiration. *Eur. J. Soil Biol.* 2006, 42, 120–126. [CrossRef]
70. Bending, G.D.; Turner, M.K.; Jones, J.E. Interactions between crop residue and soil organic matter quality and the functional diversity of soil microbial communities. *Soil Biol. Biochem.* **2002**, *34*, 1073–1082. [CrossRef]

71. Wardle, D. A comparative assessment of factors which influence microbial biomass carbon and nitrogen levels in soil. *Biol. Rev.* **1992**, *67*, 321–358. [CrossRef]

72. Subrahmaniyam, K.; Kalaiselvan, P.; Balasubramanian, T.N.; Zhou, W. Crop productivity and soil properties as affected by polyethylene film mulch and land configurations in groundnut (*Arachis hypogaea* L.). *Arch. Agron. Soil Sci.* **2006**, *52*, 79–103. [CrossRef]

73. Tu, C.; Ristaino, J.B.; Hu, S. Soil microbial biomass and activity in organic tomato farming systems: Effects of organic inputs and straw mulching. *Soil Biol. Biochem.* **2006**, *38*, 247–255. [CrossRef]

74. Acosta-Martínez, V.; Reicher, Z.; Bischoff, M.; Turco, R.F. The role of tree leaf mulch and nitrogen fertilizer on turfgrass soil quality. *Biol. Fertil. Soils* **1999**, *29*, 53–61. [CrossRef]

75. Ferren, N.; Freeman, C.; Reynolds, B. Observations of a seasonally shifting thermal optimum in peatland carbon-cycling processes; implications for the global carbon cycle and soil enzyme methodologies. *Soil Biol. Biochem.* **2005**, *37*, 1814–1821. [CrossRef]

76. Wang, C.; Long, R.; Wang, Q.; Liu, W.; Jing, Z.; Zhang, L. Fertilization and litter effects on the functional group biomass, species diversity of plants, microbial biomass, and enzyme activity of two alpine meadow communities. *Plant Soil* **2010**, *331*, 377–389. [CrossRef]

77. Krupinsky, J.M.; Bailey, K.L.; McMullen, M.P.; Gossen, B.D.; Turkington, T.K. Managing plant disease risk in diversified cropping systems. *Agron. J.* **2002**, *94*, 198–209. [CrossRef]

78. Ding, X.; Zhang, B.; Zhang, X.; Yang, X.; Zhang, X. Effects of tillage and crop rotation on soil microbial residues in a rainfed agroecosystem of northeast China. *Soil Tillage Res.* **2011**, *114*, 43–49. [CrossRef]

79. Adl, S.M.; Coleman, D.C.; Read, F. Slow recovery of soil biodiversity in sandy loam soils of Georgia after 25 years of no-tillage management. *Agric. Ecosyst. Environ.* **2006**, *114*, 323–334. [CrossRef]

80. Hydbom, S.; Erfurts, M.; Birgander, J.; Holland, J.; Jensen, E.S.; Olsson, P.A. Reduced tillage stimulated symbiotic fungi and microbial saprotrophs, but did not lead to a shift in the saprotrophic microorganism community structure. *Appl. Soil Ecol.* **2017**, *119*, 104–114. [CrossRef]

81. Wilhelm, W.; Wortmann, C.S. Tillage and rotation interactions for corn and soybean grain yield as affected by precipitation and air temperature. *Agron. J.* **2004**, *96*, 425–432. [CrossRef]

82. Meriles, J.M.; Gil, S.V.; Haro, R.J.; March, G.J.; Guzman, C.A. Glyphosate and Previous Crop Residue Effect on Deleterious and Beneficial Soil-borne Fungi from a Peanut—Corn—Soybean Rotations. *J. Phytopathol.* **2010**, *154*, 309–316. [CrossRef]

83. Fatemi, F.R.; Fernandez, I.J.; Simon, K.S.; Dail, D.B. Nitrogen and phosphorus regulation of soil enzyme activities in acid forest soils. *Soil Biol. Biochem.* **2016**, *98*, 171–179. [CrossRef]

84. Masto, R.E.; Chhonkar, P.K.; Singh, D.; Patra, A.K. Changes in soil biological and biochemical characteristics in a long-term field trial on a sub-tropical incipientis. *Soil Biol. Biochem.* **2006**, *38*, 1577–1582. [CrossRef]

85. Sinsabaugh, R.L.; Lauber, C.L.; Weintraub, M.N.; Ahmed, B.; Zeglin, L.H. Stoichiometry of soil enzyme activity at global scale. *Ecol. Lett.* **2008**, *11*, 1252–1264. [CrossRef] [PubMed]

86. Muñoz, K.; Thiele-Bruhn, S.; Kenngott, K.G.; Meyer, M.; Diehl, D.; Steinmetz, Z.; Schaumann, G.E. Effects of plastic versus straw mulching systems on soil microbial community structure and enzymes in strawberry cultivation. *Soil Sys.* **2022**, *6*, 21. [CrossRef]

87. Siczek, A.; Frac, M. Soil microbial activity as influenced by compaction and straw mulching. *Int. Agrophysics* **2012**, *26*, 65–69. [CrossRef]

88. Fontaine, S.; Mariotti, A.; Abbadié, L. The priming effect of organic matter: A question of microbial competition? *Soil Biol. Biochem.* **2003**, *35*, 837–843. [CrossRef]

89. Qian, X.; Gu, J.; Pan, H.-j.; Zhang, K.-Y.; Sun, W.; Wang, X.-J.; Gao, H. Effects of living mulches on the soil nutrient contents, enzyme activities, and bacterial community diversities of apple orchard soils. *Eur. J. Soil Biol.* **2015**, *70*, 23–30. [CrossRef]

90. Acosta-Martínez, V.; Tabatabai, M. Tillage and residue management effects on arylamidase activity in soils. *Biol. Fertil. Soils* **2001**, *34*, 21–24.

91. Elfrstrand, S.; Båth, B.; Mårtensson, A. Influence of various forms of green manure amendment on soil microbial community composition, enzyme activity and nutrient levels in leek. *Appl. Soil Ecol.* **2007**, *36*, 70–82. [CrossRef]

92. Balota, E.L.; Colozzi Filho, A.; Andrade, D.S.; Dick, R.P. Long-term tillage and crop rotation effects on microbial biomass and C and N mineralization in a Brazilian Oxisol. *Soil Tillage Res.* **2004**, *77*, 137–145. [CrossRef]

93. Ge, G.F.; Li, Z.J.; Zhang, J.; Wang, L.G.; Xu, M.G.; Zhang, J.B.; Wang, J.K.; Xie, X.L.; Liang, Y.C. Geographical and climatic differences in long-term effect of organic and inorganic amendments on soil enzymatic activities and respiration in field experimental stations of China. *Ecol. Complex.* **2009**, *6*, 421–431. [CrossRef]

94. Jin, K.; Sleutel, S.; Buchan, D.; Neve, S.D.; Cai, D.X.; Gabriels, D.; Jin, J.Y. Changes of soil enzyme activities under different tillage practices in the Chinese Loess Plateau. *Soil Tillage Res.* **2009**, *104*, 115–120. [CrossRef]

95. Wei, Z.; Wu, S.; Zhou, S.; Lin, C. Installation of impervious surface in urban areas affects microbial biomass, activity (potential C mineralisation), and functional diversity of the fine earth. *Soil Res.* **2013**, *51*, 59–67. [CrossRef]

96. Meyer, M.; Diehl, D.; Schaumann, G.E.; Muñoz, K. Multiannual soil mulching in agriculture: Analysis of biogeochemical soil processes under plastic and straw mulches in a 3-year field study in strawberry cultivation. *J. Soils Sediments* **2021**, *21*, 3733–3752. [CrossRef]
97. Pinamonti, F. Compost mulch effects on soil fertility, nutritional status and performance of grapevine. *Nutr. Cycl. Agroecosyst.* 1998, 51, 239–248. [CrossRef]

98. Duda, G.P; Guerra, J.G.M.; Monteiro, M.T.; De-Polli, H.; Teixeira, M.G. Perennial herbaceous legumes as live soil mulches and their effects on C, N and P of the microbial biomass. *Sci. Agric.* 2003, 60, 139–147. [CrossRef]

99. Jordán, A.; Zavala, L.M.; Gil, J. Effects of mulching on soil physical properties and runoff under semi-arid conditions in southern Spain. *Catena* 2010, 81, 77–85. [CrossRef]

100. Liu, X.J.; Wang, J.C.; Lu, S.H.; Zhang, F.S.; Zeng, X.Z.; Ai, Y.W.; Peng, S.B.; Christie, P. Effects of non-flooded mulching cultivation on crop yield, nutrient uptake and balance in rice–wheat cropping systems. *Field Crops Res.* 2003, 83, 297–311. [CrossRef]

101. Fan, M.; Jiang, R.; Liu, X.; Zhang, F.; Lu, S.; Zeng, X.; Christie, P. Interactions between non-flooded mulching cultivation and varying nitrogen inputs in rice-wheat rotations. *Field Crops Res.* 2005, 91, 307–318. [CrossRef]

102. Malhi, S.S.; Lemke, R.; Wang, Z.H.; Chhabra, B.S. Tillage, nitrogen and crop residue effects on crop yield, nutrient uptake, soil quality, and greenhouse gas emissions. *Soil Tillage Res.* 2006, 90, 171–183. [CrossRef]

103. Wang, H.; Zheng, J.; Fan, J.; Zhang, F.; Huang, C. Grain yield and greenhouse gas emissions from maize and wheat fields under plastic film and straw mulching: A meta-analysis. *Field Crops Res.* 2021, 270, 108210. [CrossRef]

104. Zheng, J.; Wang, H.; Fan, J.; Zhang, F.; Guo, J.; Liao, Z.; Zhuang, Q. Wheat straw mulching with nitrification inhibitor application improves grain yield and economic benefit while mitigating gaseous emissions from a dryland maize field in northwest China. *Field Crops Res.* 2021, 265, 108125. [CrossRef]

105. Hitoshi, O.; Katsuji, N.; Takuji, S.; Haruo, T.; Toshio, H.; Yoshimi, Y.J.; Kazuyuki, Y. Emission of N\textsubscript{2}O from a Satsuma Mandarin Orchard under Mulching Cultivation in Central Japan. *Eng Gakkai Zasshi* 2007, 76, 279–287.

106. Johnson, J.; Hough-Goldstein, J.; Vangessel, M. Effects of straw mulch on pest insects, predators, and weeds in watermelons and other plants. *Environ. Entomol.* 2004, 33, 1267–1272. [CrossRef]

107. Liu, J.; Zhu, L.; Luo, S.; Bu, L.; Chen, X.; Yue, S.; Li, S. Response of nitrous oxide emission to soil mulching and nitrogen fertilization in semi-arid farmland. *Agric. Ecosyst. Environ.* 2014, 188, 20–28. [CrossRef]

108. Pandey, D.; Agrawal, M.; Bohra, J.S. Greenhouse gas emissions from rice crop with different tillage permutations in rice wheat system. *Agric. Ecosyst. Environ.* 2012, 159, 133–144. [CrossRef]

109. Gong, Y.; Li, P.; Sakagami, N.; Komatsuzaki, M. No-tillage with rye cover crop can reduce net global warming potential and yield-scaled global warming potential in the long-term organic soybean field. *Soil Tillage Res.* 2021, 205, 104747. [CrossRef]

110. Hanaki, M.; Ito, T.; Saigusa, M. Effect of no-tillage rice (*Oryza sativa* L.) cultivation on methane emission in three paddy fields of different soil types with rice straw application. *Jpn. J. Soil Sci. Plant Nutr.* 2002, 73, 135–143.

111. Linn, D.M.; Doran, J.W. Effect of water-filled pore space on carbon dioxide and nitrous oxide production in tilled and nontilled soils. *Soil Sci. Soc. Am. J.* 1984, 48, 1267–1272. [CrossRef]

112. Van Kessel, C.; Ventera, R.; Six, J.; Adviento-Borbe, M.A.; Linquist, B.; van Groenigen, K.J. Climate, duration, and N placement determine N\textsubscript{2}O emissions in reduced tillage systems: A meta-analysis. *Glob. Chang. Biol.* 2012, 19, 33–44. [CrossRef] [PubMed]

113. Dendooven, L.; Gutierrez-Oliva, V.F.; Patino-Zuniga, L.; Ramirez-Villanueva, D.A.; Verhulst, N.; Luna-Guido, M.; Marsch, R.; Montes-Molina, J.; Gutierrez-Miceli, F.A.; Vasquez-Murrieta, S. Greenhouse gas emissions under conservation agriculture compared to traditional cultivation of maize in the central highlands of Mexico. *Sci. Total Environ.* 2012, 431, 237–244. [CrossRef] [PubMed]

114. Angle, J.S.; Gross, C.M.; Hill, R.L.; Mcintosh, M.S. Soil Nitrate Concentrations under Corn as Affected by Tillage, Manure, and Fertilizer Applications. *J. Environ. Qual.* 1984, 13, 141–147. [CrossRef]

115. Palma, R.M.; Saubidet, M.I.; Rimolo, M.; Usumi, J. Nitrogen losses by volatilization in a corn crop with two tillage systems in the Argentine Pampa. *Commun. Soil Sci. Plant Anal.* 1998, 29, 2865–2879. [CrossRef]

116. Johnson, J.; Hough-Goldstein, J.; Vangessel, M. Effects of straw mulch on pest insects, predators, and weeds in watermelons and potatoes. *Environ. Entomol.* 2004, 33, 1632–1639. [CrossRef]

117. Brandsmaeter, L.; Netland, J.; Meadow, R. Yields, weeds, pests and soil nitrogen in a white cabbage-living mulch system. *Biol. Agric. Hortic.* 1998, 16, 291–309. [CrossRef]

118. Silva-Filho, R.; Santos, R.H.S.; Tavares, W.d.S.; Leite, G.L.D.; Wilcken, C.F.; Serrao, J.E.; Zanuncio, J.C. Rice-straw mulch reduces white peach aphid, *Myzus persicae* (Hemiptera: Aphididae) populations on kale, *Brassica oleracea* var. acephala (Brassicaceae) plants. *PLoS ONE* 2014, 9, e94174. [CrossRef]

119. Eden, G.R.S.M. The impact of organic amendments, mulching and tillage on plant nutrition, *Pythium* root rot, root-knot nematode and other pests and diseases of capsicum in a subtropical environment, and implications for the development of more sustainable vegetable farmin. *Australas. Plant Pathol.* 2008, 37, 123–131.

120. MacLaren, C.; Labuschagne, J.; Swanepoel, P. Tillage practices affect weeds differently in monoculture vs. crop rotation. *Soil Tillage Res.* 2021, 205, 104795. [CrossRef]

121. Erenstein, O. Crop residue mulching in tropical and semi-tropical countries: An evaluation of residue availability and other technological implications. *Soil Tillage Res.* 2002, 67, 115–133. [CrossRef]

122. Rahman, M.A.; Chikushi, J.; Safiuzzaman, M.; Lauren, J.G. Rice straw mulching and nitrogen response of no-till wheat following rice in Bangladesh. *Field Crops Res.* 2005, 91, 71–81. [CrossRef]

123. Murungu, F.S.; Chiduza, C.; Muchaoneryera, P.; Mnkeni, P.N.S. Mulch effects on soil moisture and nitrogen, weed growth and irrigated maize productivity in a warm-temperate climate of South Africa. *Soil Tillage Res.* 2011, 112, 58–65. [CrossRef]
124. Ilnicki, R.D.; Enache, A.J. Subterranean clover living mulch: An alternative method of weed control. *Agric. Ecosyst. Environ.* 1992, *40*, 249–264. [CrossRef]

125. Döring, T.F.; Brandt, M.; Heß, J.; Finckh, M.R.; Saucke, H. Effects of straw mulch on soil nitrate dynamics, weeds, yield and soil erosion in organically grown potatoes. *Field Crops Res.* 2005, *94*, 238–249. [CrossRef]

126. Sharma, P.K.; Acharya, C.L. Carry-over of residual soil moisture with mulching and conservation tillage practices for sowing of rainfed wheat (*Triticum aestivum* L.) in north-west India. *Soil Tillage Res.* 2000, *57*, 43–52. [CrossRef]

127. Shi, Z.H.; Yue, B.J.; Wang, L.; Fang, N.F.; Wang, D.; Wu, F.Z. Effects of Mulch Cover Rate on Interrill Erosion Processes and the Size Selectivity of Eroded Sediment on Steep Slopes. *Soil Sci. Soc. Am. J.* 2013, *77*, 257–267. [CrossRef]

128. Prosdocimi, M.; Jordan, A.; Tarolli, P.; Keesstra, S.; Novara, A.; Cerda, A. The immediate effectiveness of barley straw mulch in reducing soil erodibility and surface runoff generation in Mediterranean vineyards. *Sci. Total Environ.* 2016, *547*, 323–330. [CrossRef]

129. Shi, Z.H.; Yue, B.J.; Wang, L.; Fang, N.F.; Wang, D.; Wu, F.Z. Effects of Mulch Cover Rate on Interrill Erosion Processes and the Size Selectivity of Eroded Sediment on Steep Slopes. *Soil Sci. Soc. Am. J.* 2013, *77*, 257–267. [CrossRef]

130. Xu, G.; Zhang, T.; Li, Z.; Li, P.; Cheng, Y.; Cheng, S. Temporal and spatial characteristics of soil water content in diverse soil layers on land terraces of the Loess Plateau, China. *Catena* 2017, *158*, 20–29. [CrossRef]

131. Zhao, B.; Li, Z.; Li, P.; Xu, G.; Gao, H.; Cheng, Y.; Chang, E.; Yuan, S.; Zhang, Y.; Feng, Z. Spatial distribution of soil organic carbon and its influencing factors under the condition of ecological construction in a hilly-gully watershed of the Loess Plateau, China. *Geoderma* 2017, *296*, 10–17. [CrossRef]

132. Favaretto, N.; Cherobim, V.F.; de Medeiros Silveira, E.; Timofiecsy, A.; Skalitz, R.; Barth, G.; Pauletti, V.; Dieckow, J.; Vezzani, F.M. Can application of liquid dairy manure onto no-tillage oxilos reduce runoff, sediment, phosphorus, and nitrogen losses over 9 years of natural rainfall? *Geoderma* 2022, *405*, 115406. [CrossRef]

133. Holland, J.M. The environmental consequences of adopting conservation tillage in Europe: Reviewing the evidence. *Agric. Ecosyst. Environ.* 2004, *103*, 1–25. [CrossRef]

134. Jia, Y.; Li, F.M.; Wang, X.L.; Yang, S.M. Soil water and alfalfa yields as affected by alternating ridges and furrows in rainfall harvest management practices: Resource capture and use efficiency. *Agric. Water Manag.* 2010, *97*, 167–175. [CrossRef]

135. Zhou, L.-M.; Li, F.-M.; Jin, S.-L.; Song, Y. How two ridges and the furrow mulched with plastic film affect soil water, soil temperature and yield of maize on the semiarid Loess Plateau of China. *Field Crops Res.* 2009, *113*, 41–47. [CrossRef]

136. Jia, Y.; Li, F.M.; Wang, X.L.; Yang, S.M. Soil water and alfalfa yields as affected by alternating ridges and furrows in rainfall harvest in a semi-arid environment. *Field Crops Res.* 2006, *97*, 167–175. [CrossRef]

137. Arora, V.K.; Singh, C.B.; Sidhu, A.S.; Thind, S.S. Irrigation, tillage and mulching effects on soybean yield and water productivity in relation to soil texture. *Agric. Water Manag.* 2011, *98*, 563–568. [CrossRef]

138. Arvidsson, J.; Etana, A.; Rydberg, T. Crop yield in Swedish experiments with shallow tillage and no-tillage 1983–2012. *Eur. J. Agron.* 2014, *52*, 307–315. [CrossRef]
151. Van den Putte, A.; Govers, G.; Diels, J.; Langhans, C.; Clymans, W.; Vanuytrecht, E.; Merckx, R.; Raes, D. Soil functioning and conservation tillage in the Belgian Loam Belt. *Soil Tillage Res.* **2012**, *122*, 1–11. [CrossRef]

152. Mcmaster, G.S.; Palic, D.; Dunn, G.H. Soil management alters seedling emergence and subsequent autumn growth and yield in dryland winter wheat–fallow systems in the Central Great Plains on a clay loam soil. *Soil Tillage Res.* **2002**, *65*, 193–206. [CrossRef]

153. Rockström, J.; Kaumbutho, P.; Mvalley, J.; Nzabi, A.; 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]

154. Ashworth, A.J.; Allen, F.L.; Saxton, A.M.; Tyler, D.D. Long-term corn yield impacted by cropping rotations and bio-covers under no-tillage. *Agron. J.* **2016**, *108*, 1495–1502. [CrossRef]

155. Zhao, H.; Mao, A.; Yang, H.; Wang, T.; Dou, Y.; Wang, Z.; Malhi, S. Summer fallow straw mulching and reducing nitrogen fertilization: A promising practice to alleviate environmental risk while increasing yield and economic profits of dryland wheat production. *Eur. J. Agron.* **2022**, *133*, 126440. [CrossRef]

156. Neugschwandtner, R.W.; Kaul, H.P.; Liebhard, P.; Wagentristl, H. Winter Wheat Yields in a Long-Term Tillage Experiment under Pannonian Climate Conditions. *Plant Soil Environ.* **2015**, *61*, 145–150.

157. Huang, T.; Yang, N.; Lu, C.; Qin, X.; Siddique, K.H. Soil organic carbon, total nitrogen, available nutrients, and yield under different straw returning methods. *Soil Tillage Res.* **2021**, *214*, 105171. [CrossRef]

158. Desta, B.T.; Gezahegn, A.M.; Tesema, S.E. Impacts of tillage practice on the productivity of durum wheat in Ethiopia. *Cogent Food Agric.* **2021**, *7*, 1869382. [CrossRef]

159. Van Ittersum, M.K. Crop Yields and Global Food Security. Will Yield Increase Continue to Feed the World? *Eur. Rev. Agric. Econ.* **2016**, *43*, 191–192. [CrossRef]