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Review Article

An Overview of the Impact of Tillage and Cropping Systems on Soil Health in Agricultural Practices

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There is currently a demand to grow more crops in less area as a result of urbanization's reduction of agricultural land. As a result, soil fertility is gradually declining. To maintain soil fertility, various management methods are used in modern times. The conventional tillage method is a traditional tillage method that damages soil structure, but zero tillage can improve soil quality. By maintaining soil structure with no-tillage, biological processes are frequently improved and microbial biodiversity is increased. This review helps to understand the role of tillage as well as cropping systems in increasing crop production by maintaining soil fertility. For agricultural production and environmental protection to be sustained for future generations, soil quality must be maintained and improved in continuous cropping systems. The nodulation, nitrogen fixation, and microbial community are all impacted by different cropping systems and tillage methods. They also alter soil properties including structure, aeration, and water utilization. The impact of tillage and cropping system practices such as zero and conventional tillage systems, crop rotation, intercropping, cover cropping, cultivator combinations, and prairie strip techniques on soil fertility is carefully summarized in this review. The result highlights that conservational tillage is much better than conventional tillage for soil quality and different aspects of different tillage and their interaction. On the other hand, intercropping, crop rotation, cover cropping, etc., increase the crop yield more than monocropping. Different types of cropping systems are highlighted along with their advantages and disadvantages. Using zero tillage can increase crop production as well as maintain soil fertility which is highlighted in this review. In terms of cropping systems and tillage management, our main goal is to improve crop yield while minimizing harm to the soil's health.

1. Introduction

Soil has a fundamental role in crop production [1]. Crops need fertile land to produce adequate amounts of yield [2]. Retaining soil fertility has become a major challenge in today's world [3]. Wind and water erosion, salinization, compaction, and severe nutrient depletion have been caused by inadequate clearance techniques, unsuitable land use practices, overgrazing, and overexploitation. The afflicted area is still expanding, and a massive amount of the land surface is currently severely deteriorated [4]. High-yielding cultivars, pesticides, and chemical fertilizers have increased agricultural output via the Green Revolution, but they have also caused environmental contamination and biodiversity loss in agricultural systems [5]. In terms of agroecosystem production, intensive agriculture has made great strides. Currently used growing systems favor the sound environment, which includes extensive expanses of cultivated land, and replaces the diversity of native plant life with other cultivars or monocultures of certain cultivars [6]. This not only results in the depletion of resources for cultivated plants but also reduces many advantages that biodiversity in agroecosystems offers. As a result, it is vital to comprehend the mechanisms used in agricultural systems to diversify in ways that promote soil fertility and higher yields [7, 8]. It is undeniable that different cropping systems and tillage help preserve soil fertility and biodiversity [9].

High-yield crop growth is not solely a result of good soil management measures. The growth of crops is very climate-sensitive. Long-term trends in average precipitation, interannual climate variability, shocks at certain phenological stages, temperature, and extreme weather events all have an impact on it. Even though increased CO_2 can promote plant development [10], it also lowers the nutritional content of the majority of food crops [11]. Most plant species, including soybeans, wheat, and rice, have critical mineral and lower protein concentrations due to rising atmospheric CO_2 levels.

Cropping systems, a crucial part of a farming system, depict the cropping patterns utilized on a farm and how they interact with other farm enterprises, farm resources, and technology that is available to them. It is widely recognized that mycorrhizal fungus activity can improve soil quality. Cropping systems promote soil mycorrhizal fungi inoculation [12]. Additionally, mycorrhizal fungi aid in improving early crop growth. It develops symbiotic interactions with plant roots that can help with water and nutrient intake [13].

On the other hand, a key aspect of agronomy that affects the properties of both soil and crops is tillage. The main goal of tillage is to provide the right conditions for the growth of seedlings, the germination of seeds, and the best possible crop yields [14]. Changes in the chemical and physical characteristics of soil brought on by various tillage techniques can have an impact on elements directly related to biotic actions in the soil, including soil moisture, organic matter, temperature, and ventilation in addition to the degree of interaction among soil organic matter and nutrients [15].

Tillage practice and cropping systems is essential to maintain soil fertility [16]. As conservation tillage improve the physical condition of the soil [17], the cropping system removes the deficiency of any nutrient element in the soil [18]. So far, many reviews on cropping systems and tillage have been performed separately [19–22]. But this review brings the two issues together and highlights the role of tillage and cropping systems on soil fertility and soil management. In this review, we highlight the latest cropping systems in agriculture as well as their benefit on crop production. People may easily understand the difference between existing cropping systems and which can cope with modern agriculture through this review. Our main target is to increase crop production with minimum damage to soil health from the perspective of cropping systems and tillage management. This review finds the best way and indicates the specific importance of tillage and cropping systems to maintain soil health and increase crop production.

2. Cropping System and Its Benefits on Soil

2.1. Cropping System. Cropping systems used in agriculture, such as crop diversification, crop rotation, and intercropping, have an impact on soil quality and health from a variety of temporal and spatial perspectives [23]. Cropping systems were first created to increase the production from agro-systems, however, modern agriculture is becoming more concerned with cropping systems' environmental sustainability [24]. Below is a discussion of different multiple-cropping systems compared to mono-cropping to preserve and improve soil fertility (Figure 1).

2.1.1. Crop Rotations. Growing several crops on the same land during various seasons is known as crop rotation. It is one of the best methods for preventing soil-borne diseases [25]. For managing the specific infections that are present, the rotation design is crucial [13]. As an illustration, root colonization by bacteria and archaea is impacted by crop rotation between upland maize and marsh rice [26, 27]. Crop rotation impacts seed banks, which is proven by how consecutive crops require different weed management strategies [28, 29]. Those weeds that endure and generate seeds during one crop add to the seed bank from which weed seedlings are attracted throughout subsequent crops. There are more opportunities for weed mortality events in rotations than in monocultures due to more variety in the type and timing of soil, crop, and weed management methods [29]. Crop yield, nutrient leaching, the presence of weeds, pests, and diseases, and crop rotation performance are all considered when evaluating crop rotation's effectiveness. Other studies looking at how crop rotation affects soil fertility and insect proliferation use the experiment as a workspace [6, 30]. An experiment was carried out to determine the impact of soil tillage and crop rotation in northern agricultural systems. Under no-tillage and plowing, three forms of crop rotation were compared: monoculture, two-year rotation, and four-year rotation. A diversified crop rotation enhanced spring wheat output by up to thirty percent with no-tillage and by thirteen percent under the plow as compared to monoculture [31].

Overall, no-tillage plots showed higher yield quantity and quality variations than plowed plots between crop cycles. The crop rotation with the widest variety of crops had the lowest severity of a plant disease, wheat leaf blotch disease. In comparison to wheat monoculture, the average severity of the wheat leaf blotch disease was 20% lower when wheat was cultivated every fourth year. Stem and root disease were the least common in crop rotations with the most diverse crop mix [31]. Crop rotation is a useful strategy for controlling a wide range of illnesses and pests (Table 1) [32].

2.1.2. Intercropping. Multicropping, also known as intercropping, is a centuries-old agricultural strategy that entails planting many crop species adjacent to one another so that they cohabit for a sizable portion of their life cycles [33, 34]. Due to the existence of land being used for nonagricultural purposes, the amount of land that is available for agriculture is decreasing daily. In this context, developing a highly intensive sequential cropping system that intercrops is one of the key techniques to boost agricultural output [35]. Intercropping often involves one main crop and one or more

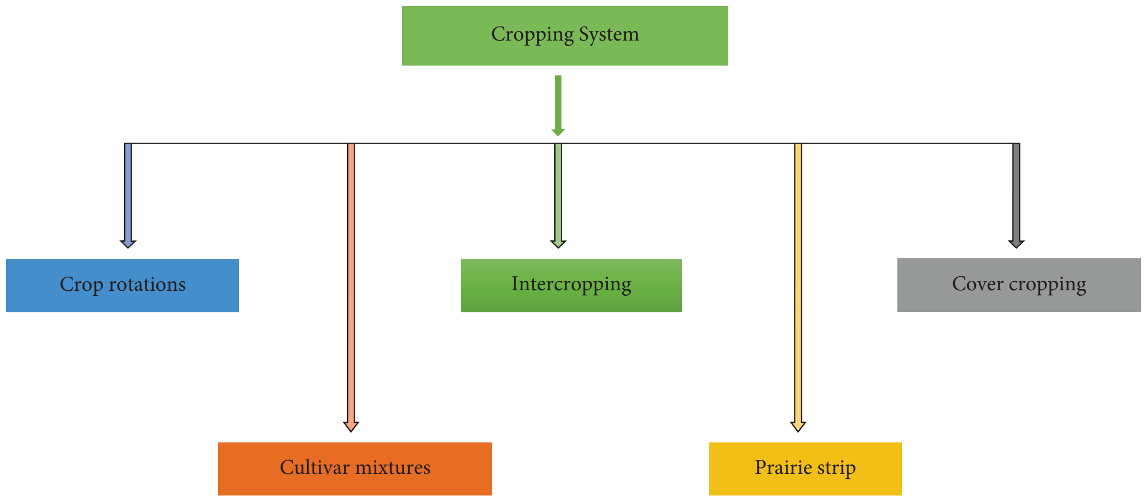

Figure 1: Different types of cropping system.

additional crops, with the main crop having the most economic significance. In an intercropping system, two or more crops of preferably unrelated varieties are planted. Intercropping can involve growing an annual crop alongside an annual intercrop, an annual crop alongside a perennial intercrop, or perennial crops alongside a perennial intercrop [36]. Without a doubt, sequential cropping systems benefit farmers in a variety of ways, including increased productivity, better resource utilization, and financial gain [35]. Intercropping comes in four different forms and is used all over the world.

(i) Row intercropping:

Row intercropping is the practice of cultivating two or more crops concurrently, where one or more crops are grown in regular rows and another crop or crops may be produced simultaneously in a row or may be grown at random with the first crop.

(ii) Mixed Cropping:

The act of cultivating two or more crops side by side without a distinct row pattern is known as mixed intercropping. Grass-legume intercropping in a pasture-based system may be appropriate for this type of planting system.

(iii) Strip intercropping:

The act of cultivating two or more crops simultaneously in distinct strips that are both wide enough to permit independent cultivation and thin enough to permit agronomic influence.

(iv) Relay intercropping:

Relay intercropping involves having two crops in the field at once for a period of time. In this technique, the second crop is planted after the first has reached reproductive maturity but before the first is ready for harvest.

When the experiment was carried out in West Bengal, India's red and lateritic belts, it was discovered that intercropping finger millet with pea gourd and groundnut registered higher net returns and benefit-cost ratios than the combination of finger millet with green gram and soybean with the same row population. The faba bean produced more biomass and more grain when it was intercropped with maize, the yield of the faba bean was recorded as being lower when it was intercropped with wheat [37]. Yield improvements have been observed when compared to equivalent sole crops. Grain yields in intercropped systems were found to be on average 22% higher than in comparable monocultures and to have improved year-to-year consistency using four lengthy (10–16 years) studies on soils of varying fertility [38].

The basic goal of intercropping is to promote more significant biological and crop interactions. It has been found that the use of intercropping, little tillage, and organic fertilizer improved the soil's fertility and maintained the amount of ground cover necessary to protect the soil [39]. Compared to when they are cultivated as a single crop, intercrop components are less susceptible to pests and disease organisms. Comparing solitary cropping and row cropping to mixed intercropping, the incidence of common bacterial blight was reduced by an average of 23% and 5%, respectively. It has been suggested that intercropping wheat with different crop species can lessen the harm that powdery mildew and stripe rust do [40]. It has been discovered that, through a variety of mechanisms, intercropping with marigolds significantly reduced the incidence of *Alternaria solani* which causes late blight in tomatoes [41].

2.1.3. Cover Cropping. Any living ground cover that is planted next to or after the primary crop and frequently removed before the following crop is sown is known as a cover crop. Cover crops occasionally entail double cropping into one main crop in order to decrease soil erosion, pests, and weeds and increase organic matter (Table 1). Other methods of using cover crops include relay cropping, overseeding, and interseeding [42]. With the advent of herbicides and synthetic fertilizers, the utilization of these systems was drastically curtailed [42].

Table 1: Major role of different cropping systems in soil with example.

Cropping system	Major role	Suitable crops
Crop rotations	Without using synthetic inputs, aids in restoring nutrients to the soil	Mostly soybeans and corn
Intercropping	Increase plant resource efficiency and encourage the natural control of weeds, diseases, and insect pests to increase climate resilience	Cowpea, beans, groundnut, leguminous crops, soybean, maize, corn, wheat, etc
Cover cropping	Enhancing the biological, chemical, and physical characteristics of soil	Wheat, ryegrass, *pennisetum*, lablab, cowpea sorghum, millet, oats, barley, alfalfa hairy vetch, red and white clover fava, Austrian winter pea, triticale, etc
Cultivar mixtures	Control several diseases	Maize, barley, wheat, snap beans, etc
Prairie strip	Improve water quality, decrease soil erosion, and promote biodiversity	Mostly corn and soybean

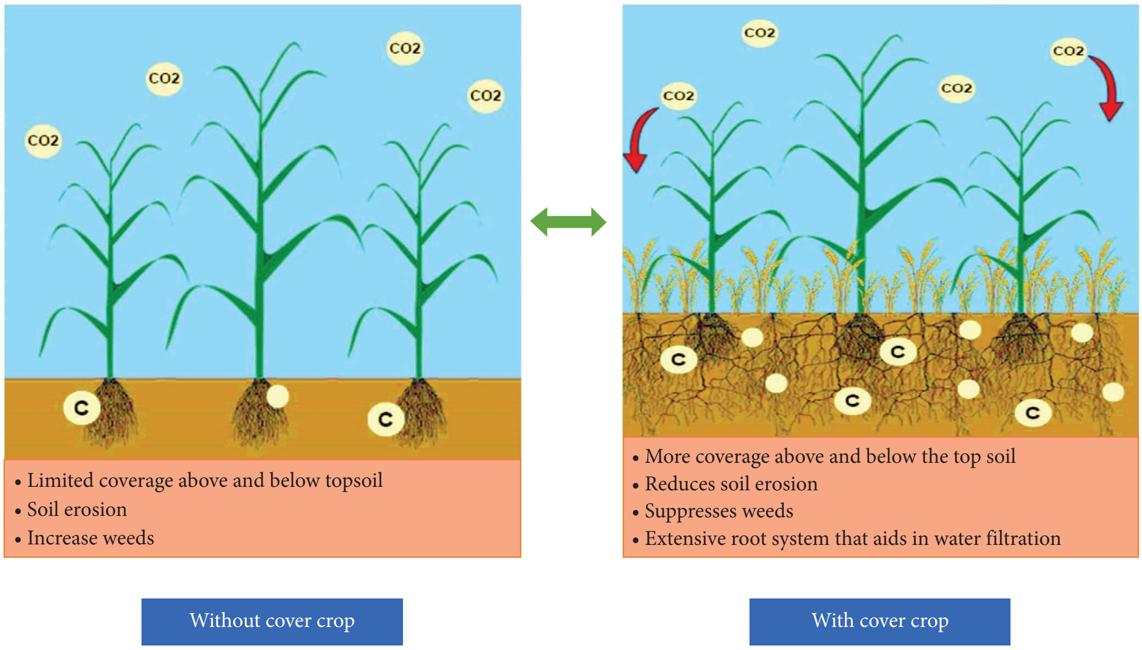

Figure 2: Difference between the cultivation with and without cover crop.

According to Drinkwater and Snapp [43], cover crops have a significant potential to improve cropping systems' functional diversity and environmental sustainability. In an annual cropping system, growing an understory crop or cover crop alongside or after a cash crop may satisfy a geographical or temporal niche. In areas with shorter growing seasons, interseeding or relay cropping is a common strategy for establishing and reaping the benefits of a cover crop. It has received some attention in the northern great plains (NGP) [44].

Relay cropping is a popular technique for establishing and utilizing a cover crop in regions with shorter growing seasons. This strategy has attracted some attention in the NGP [44, 45]. There are no appreciable losses in grain output, according to studies on the sustainability of cover cropping in cereals in Manitoba, Canada. [46]. Additionally, it may stop the spread of disease spores onto the crop [47]. But it frequently comes with issues with weed control and yield reduction. From this vantage point, cover crops may be crucial in reducing weed infestation and maintaining productivity. Long-term experiments revealed that cover crop cultivation, particularly in reduced tillage regimens, could significantly enhance soil organic carbon and total nitrogen. Any crop cultivated for soil improvement and protection as opposed to crop production is referred to as a cover crop. The prevention of soil erosion, biological N_2 fixation, weed or insect suppression, and other objectives may be more specific objectives of cover crops (Figure 2).

As a result, cover crops have a lot of potentials to boost cropping systems' functional variety and environmental sustainability [43]. A cropping system's available spatial and temporal niches must be carefully analyzed before selecting a cover crop species and a means for incorporating it [46, 48].

2.1.4. Cultivar Mixtures. Agronomically suitable cultivar combinations called cultivar mixtures lack any further phenotypic uniformity breeding. Growing mixes of several crop cultivars could be one way to boost genetic variety without significantly raising crop management complexity. Contrary to expectations, ecological interactions may be more influenced by intraspecific genetic diversity (Table 1).

Boosting biodiversity through variety mixing had a similar impact on primary plant productivity as doing so through species mixtures, but the diversity of arthropods increased less [49]. Cultivar mixes may even help improve yield stability and yield in cultivars that would otherwise yield less, according to Mengistu et al. [50]. The disease control brought about by the genetically diverse cultivars in the mixtures is the crucial factor in maintaining grain yield and quality in cultivar combinations [51]. Cultivar combinations have been utilized successfully in spring wheat crops in the US, Germany, and Europe as well as spring barley crops to lessen yield losses brought on by the leaf disease [52, 53]. However, other researchers have not found any advantages in combining cultivars [54].

Therefore, it is crucial to choose cultivars for the mixture that can lessen the diseases that the crops are likely to encounter. If the mixture's constituent parts are pertinent to the pressures posed by the pathogens, then the suppression of diseases may be all but complete.

2.1.5. Prairie Strip. Prairie strips are a type of conservation measure that safeguards soil and water while also providing animal habitats. Prairie strips, a relatively new conservation cropping technique for farms [55, 56], have demonstrated advantages for enhancing soil health, safeguarding the environment, and supplying wildlife. Compared to other perennial vegetation types, prairie strips offer these

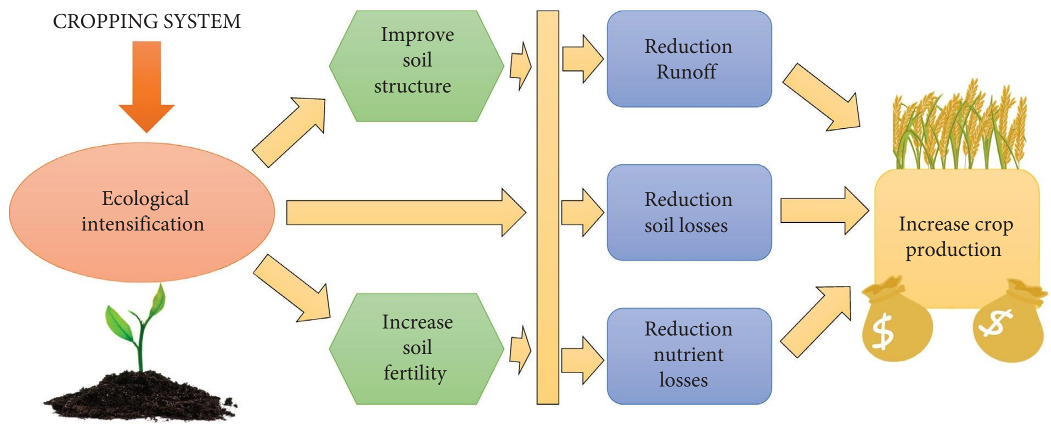

Figure 3: Role of cropping systems to improve soil health as well as crop production.

disproportionate benefits to a greater extent due to the variety of native plant species they contain, their deep multilayered root systems, and their rigid stems that can withstand heavy rain. Prairie strips are among the most readily available and cost-effective agricultural conservation strategies, according to the STRIPS (Science-based Trails of Row Crops Integrated with Prairie Strips) study [57].

In agroecosystems, prairie strips present less of a management issue while improving nutrient retention, soil organic matter content, and soil water infiltration (Table 1) [58]. While longer crop rotations can lower the prevalence of soil diseases and improve the economic benefits of some additional crops, such as minor grains and forages, they also call for more manpower, tools, and management techniques. To improve ecosystem services for soil health, prairie strip methods could be integrated with other crop rotations [59]. In order to meet both environmental and economic goals, perennial native grass species grown in rotation with other crops, for instance, provide significant opportunities for diversification [60, 61], but the levels of benefits provided by prairie strips are higher.

2.2. Role of Cropping System on Soil Health. The category of crops that are grown on a certain plot of land following a definite sequence of crops over a set period is known as cropping system. The process defines how they interact with other agricultural companies and farm resources. It covers every facet of supervision and agricultural coordination in terms of time and space. Depending on the precise rotation of crops, amendments of nutrients, and tillage techniques used, cropping systems can have an impact on a variety of soil qualities (Figure 3). It may either benefit environmental conditions or cause the soil quality to deteriorate, improve, or remain unchanged over time. By combining altered signs of fitness of soil health which include physicochemical properties of the soil, soil microorganism's eminence, and cropping practices into indices in agroecosystems, momentous endeavors, inclusive of refinement of the content material of soil health, and the improvement of novel evaluation standards for quality and health of the soil can be used to evaluate and undeviate soil and management decisions of crops.

The cornerstone for crafting innovative novel tools and methodologies for evaluating biological physiognomies of soil and procedures is strengthening the scientific foundation for the assessment of soil health. The tools and methodology include genomic advancements such as sequencing, bioinformatics, and mapping. The impact of phylogenesis on the quality and strength of soil is a scorching topic for novel investigation strategies. These can be innovative approaches for commercial investments, even though the biology of the soil has been advanced and esteemed as a crucial part of pedology for epochs. The foundation of *in-situ* sensors such as accessible carbon in the soil, soil pH, soil bulk density capacity of the soil, and microbial activity that can proficiently evaluate the biotic and abiotic markers is an imminent opportunity to upsurge soil health assessment [62]. These strategies will significantly advance the field of soil health and strength assessments, as well as the ability to sustainably improve soil health and quality.

Additionally, inclusive developments in the biology of soil, fresh IT innovation, and metadata analyzing methods for deciphering and synthesizing data on soil quality indicators under various climatic and edaphic circumstances will result in additional trustworthy recommendations. It will enhance imperishable land management and aid in reducing and preventing the comprehensive degradation of soil [13]. Some environmentally friendly cultivation practices such as crop rotation, intercropping, shifting cultivation, contour strip cropping, relay cropping, and cover crops can improve the vigor of the soil by lowering artificial chemical pollution [63]. Such a type of traditionally structured cropping system not only balanced the ecosystem but also maximized the yields of the crops.

Crop rotation aids in plummeting the raindrop's impacts on the soil and overall attrition of water such as splash erosion and rill erosion as the underground parts of the plants mainly roots grasp the topmost stratum of the soil. Integration of crops on a farm along with trees (agroforestry) assists to avert soil erosion. Along with contributing a variety of ecosystem amenities, biomass and soil carbon pools also consume more atmospheric carbon dioxide than the sequester. To reap the greatest environmental and economic benefits in ravine areas, agroforestry may be a promising strategy [64]. Such multiple amalgamations increase the diversity of crops, improve the performance of the agricultural system, and spare space for biodiversity. It helps reduce the usage of formulated inorganic fertilizers and pesticides, which have negative impacts on the environment. Pesticide use has been concomitant to numerous documented negative effects on the environment, including the poisoning of commercial honeybees and wild pollinators of fruits and vegetables, the eradication of natural pest-controlling predators in agricultural and natural ecosystems, the contamination of ground- and surface-water with pesticide residues, the extinction of fish and other aquatic organisms, mammals, birds, microorganisms, and invertebrates, and population shifts of plants and animals within the ecosystem toward more tolerant species.

Utilizing the available resources more effectively is made possible by having a variety of crops. During the growing season, plants equally distribute natural resources such as nutrients, sunlight, and groundwater in the soil, plummeting the likelihood of nutrient deficits and drought. The conversion to sustainable amplification of crop production systems is being facilitated through resource conservation [65]. It will enhance the quality of the soil and prevent soil erosion by forming crusts and causing sedimentation. Crop rotation assists in replenishing soil nutrients without using artificial inputs. Additionally, the approach interrupts the disease cycle and infestation of insects and pests and boosts soil strength by accumulating biomass obtained from numerous vegetation root systems. It boosts the biodiversity on the ranch [66]. Conservation tillage can be used to lessen erosion. It helps to improve the quality of the soil by stabilizing the soil as it loosens, suppressing weeds, preparing the soil, and the seedbed, and preserving the soil moisture. This in turn increases the water infiltration and decreases the runoff. As a result, it reduces soil erosion [67].

Dangerous air pollutants such as methane, nitrous oxide ammonia, and hydrogen sulfide are emitted into the atmosphere as a result of the use of hazardous chemical pesticides on crops. Excessive and continuous rain is the prominent reason for agricultural run-off that exterminate chemicals from the food production zone to other areas. These run-offs will contaminate agricultural soil as well as residential land, streams, and other different agroecosystems [68]. These will degrade the quality of the ecosystem. A cropping system is crucial for lowering the danger of nitrate leaching into surface and groundwater because it increases soil nitrogen availability and reduces the need for nitrogen fertilizer.

3. Tillage and Its Role in Soil

3.1. Tillage. Tillage is the mechanical manipulation of surface soil to effect desirable changes in the physical, chemical, and biological properties of the soil to permit optimal seed germination, plant seedling growth, and enhancing plant growth and development. In a broad sense, tillage can be classified into primary and secondary tillage. Tillage that is deeper and more comprehensive is defined as primary, while tillage that is shallower and occasionally more location-specific is classified as secondary. Primary tillage causes the soil to become looser and mixes in fertilizer or plant matter, giving the soil a rough texture. Secondary tillage creates finer soil and might occasionally shape the rows to create the seed bed.

Plowing is an example of primary tillage, which typically results in a rough surface finish. Secondary tillage, on the other hand, typically results in a smoother surface finish, such as that needed to create a decent seedbed for many crops. In terms of methods or systems, there are around 5 systems that are more or less practiced by the farmers. But among all these methods, conventional and conservation tillage are the most important and discussed ways of tillage, considering soil fertility and all other characteristics.

Conservation tillage is a cutting-edge agricultural farming technique that use no-till, reduced tillage, and minimum tillage to limit soil wind erosion, water erosion, and soil pollution as well as to improve soil fertility, drought resilience, and water conservation [69, 70]. Numerous earlier researches have shown that conservation tillage has a major impact on the ecosystem services that the soil provides, such as soil fertility, nitrogen cycling, and crop productivity [71, 72].

Conventional tillage involves layer inversion (plowing). There was no residue on the surface after the crop was harvested; all that was left were the roots of the prior crop. It divides soil aggregates and creates a farm seedbed free of clods. Here, the primary sources of power are horses and animals. Later, intensive manure additionally makes use of tractor power.

The term "zero tillage" refers to a tillage strategy that only includes preparing the soil so that seeds can be sown. One of the most popular conservation tillage techniques is no-till or zero tillage, which just slightly disrupts the soil structure and helps to conserve water, moisture, and nutrients in surface soil [73]. Zero tillage is a conservation farming system in which seeds are sown into otherwise tilled soil by creating a small slot, trench, or hole that is only wide enough to accommodate the seed and deep enough to cover it properly. There is no more soil tillage.

3.2. Role of Tillage in Soil Health. Specifically, conservation tillage methods such as straw mulching, subsoiling tillage, and no-tillage have produced exceptional results in enhancing soil structure, decreasing soil erosion, and raising soil nutrient content, all of which are essential for the long-term health of the soil and the agricultural ecosystem [75, 76].

A deeper comprehension of the impact of conservation tillage on soil chemical properties (such as pH, metal cations, nutrient elements, and organic matter) is necessary to achieve sustainable agricultural development and eco-environmental protection. Conservation tillage can significantly increase the concentration of OM and OC (Table 2), nutritional elements, and other soil chemical qualities, and straw stubble covering can significantly increase these values as well [77].

Table 2: Soil organic carbon stocks are affected by soil management: a statistical data [74].

Soil depth (cm)	Soil management	At beginning ($Mg{\cdot}ha^{-1}$)	After 19 years ($Mg{\cdot}ha^{-1}$)	Difference ($Mg{\cdot}ha^{-1}$)
0–10	No-tillage	23.33	40.76	17.43
	Conventional	23.53	34.12	10.59
10–20	No-tillage	21.96	28.07	6.11
	Conventional	23.54	31.09	7.55
20–40	No-tillage	35.17	41.51	6.34
	Conventional	37.01	42.00	4.99
0–20	No-tillage	45.29	68.82	23.53
	Conventional	47.06	65.21	18.15
0–40	No-tillage	80.46	110.34	29.88
	Conventional	84.08	107.21	23.13

On the other hand, conventional tillage frequently results in significant soil and water loss, degradation of the natural environment, depletion of soil nutrients, and unsustainable agricultural production [78]. However, conservation tillage techniques can improve soil nutrients and soil tolerance to environmental changes [79, 80]. Due to the preservation of the soil structure by tillage methods, conservation tillage practices, especially no-tillage, may increase the soil fertility (Figure 4) [81, 82].

3.2.1. Soil Nutrient Content. When compared to traditional tillage, the nutrient availability on and near the soil surface is increased in no-till soils, similar to the distribution of SOC content [83].

(1) Soil Organic Matter. The organic component of soil referred to as soil organic matter (SOM) is made up of decomposing plant and animal residues, soil microbe cells and tissues, and compounds made by soil microbes. The physical, chemical, and regulatory ecosystem services that soil is capable of providing are all enhanced by SOM. It is particularly important for soil quality and function, and the availability of soil organic matter is greatly influenced by various tillage systems practiced in a particular soil. The microstructure during conventional tillage was dominated by weakly separated plates and showed the lowest soil organic matter ($3.68\,g/kg^1$) and highest bulk density ($1.49\,g/cm^3$) [84].

The OM content of the soil can be raised by using conservation tillage. After four years of conservation tillage in karst mountainous terrain, soil organic matter (OM) increased by 7% over conventional tillage [77]. After straw decomposition, soil OM content increased, soil microorganism activity and quantity increased, and straw stubble covering based on no-tillage boosted these factors. Thus, it also indicates that if the soil remains under no-tillage conditions and some other agricultural practices are implemented in the soil, then it will help in increasing the soil organic matter content.

(2) Micronutrients and Macronutrients. The macronutrients, also known as phosphorus, calcium, nitrogen, sulfur, magnesium, and potassium are all provided by the soil in quite considerable proportions. The soil provides the so-called micronutrients molybdenum, chlorine, boron, copper, cobalt, zinc, manganese, and iron in relatively modest quantities. These substances are essential for plant metabolism, development, and reproduction, as well as for their external supply. If the element is required for the plant to complete a normal life cycle, it may be an essential component of a plant ingredient or metabolite.

Tillage operations also affect the availability of these nutrients, as they are not always available for plant uptake. Conservative farming methods such as no-till, minimal till, and permanent raised beds with residue retention produced more stable aggregates and increased initial nitrogen immobilization [85]. In the first few years, higher nitrogen immobilizations can reduce crop productivity and nitrogen fertilizer recovery, but later on, they can increase crop yield and reduce nitrogen losses via leaching, surface runoff, and denitrification [86].

Various tillage practices result in varying degrees of soil crushing, which is the reason why variable soil layers have different nitrate-nitrogen concentrations. Reduced tillage without straw stubble covering can lower nitrate-nitrogen leaching loss, which encourages nitrate-nitrogen buildup in the soil layer [87]. Because there were more leftovers on the surface under the no-till method, the microbial biomass rose, which raised the P concentration [88]. However, according to Roldan et al., the kind of crop, soil depth, or tillage system had no effect on the amount of accessible phosphorus [89].

On the other hand, phosphorus (P) is easily fixed, flows more slowly through the soil, and is typically richer on the top layer. If stratified, rainfall runoff can readily wash away the majority of the soil P in the top layer. Stratification significantly lowers the utilization efficiency of P, which endangers crop growth when combined with the element's already low use efficiency. The chemical causes of aggregation in soil include exchangeable metal cations, including, sodium (Na^+), magnesium (Mg^{2+}), and calcium (Ca^{2+}) ions, which can build cationic bridges with organic carbon (OC) and clay particles to stop the OM from degrading [90].

K availability on the surface soil where crop roots were denser had increased without tillage and residue retention [91]. The pH and sodium ion (Na^+) are not significantly or inconsistently affected by conservation tillage [77]. To be more precise, conservation tillage can raise TC (total carbon), OC, OM, nutrients (N, P, and K), and their accessible

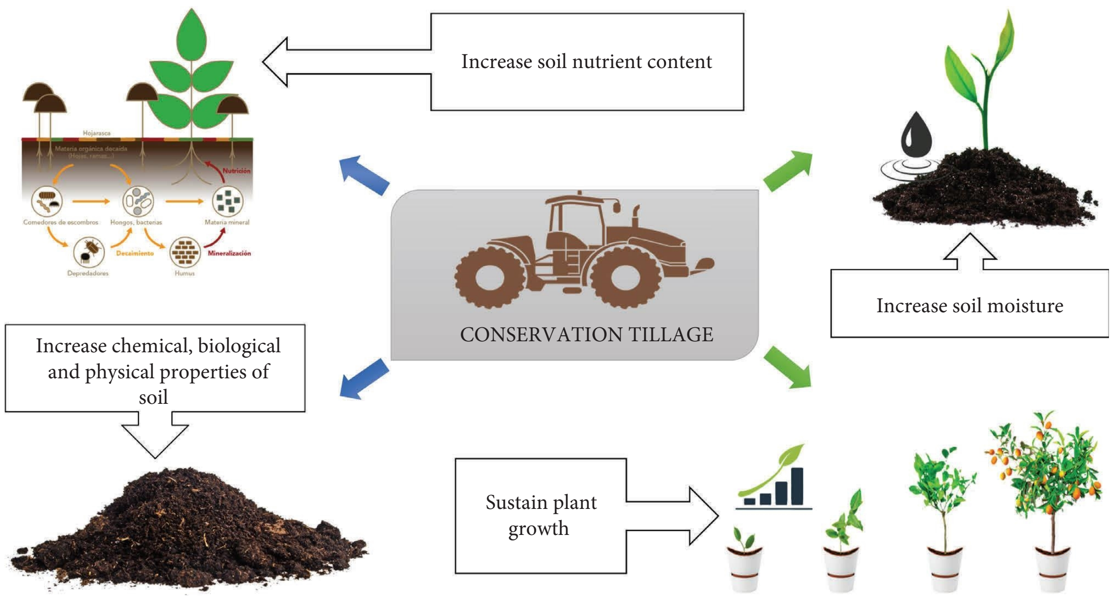

FIGURE 4: Role of conservation tillage for maintaining soil fertility.

contents; it can also enhance metal cation contents (Na^{+}, Mg^{2+}, Ca^{2+}), and CEC, increasing the number of bases and bringing the pH into balance [77, 92–94].

3.2.2. Soil Moisture. The soil's dynamic equilibrium of water or moisture, fertilizer, different gases, and heat can be greatly controlled by tillage treatment, a traditional technique for soil development [84]. But it is a fact that a tillage system that works well in one place could be a total failure in another. However, several soil variables, including soil bulk density, pore space in soil, infiltration rates, hardpans, soil surface sealing and crusting, hydraulic conductivity, and surface roughness are essential to the success of on-farm soil water conservation because they have an impact on the hydrological properties of soil [95].

One of the suitable approaches to overcoming soil moisture limits in rainfed agriculture is widely acknowledged to be soil water conservation [96]. In conservation tillage methods, plant wastes can cover more than 30% of the soil's surface [97]. This organic mulch decreases runoff, speeds up infiltration, and slows down soil water evaporation [98, 99]. Conserving soil moisture and reducing soil erosion are two benefits of conservation tillage [100]. In order to save and manage soil water under various soil types, management situations, and climates, it is vital to comprehend the effects of tillage strategies on soil hydraulic parameters. Damaged soil structure, poor soil fertility, and soil surface sealing brought on by conventional tillage methods based on moldboard plows and fine seedbeds with residue removed or buried have an effect on water infiltration and soil water retention. Other signs of these issues include low soil organic matter content, unstable soil aggregates, and low meso-porosity [101].

3.2.3. Chemical, Biological, and Physical Properties of Soil. Traditional soil management techniques such as tillage can significantly alter the dynamic balance of gas, water, heat, and fertilizer in the soil [84]. Micropores and macropores both had an impact on water infiltration, storage, drainage, aeration, and the ease with which growing roots could penetrate the soil. Both abiotic (such as thawing, freezing and tillage, and wetting and drying) and biotic (such as root growth and burrowing by fauna) processes can build or destroy pores. Inappropriate tillage techniques can move and settle soil particles, hasten nutrient mineralization and depletion, disrupt surface vented pores, reduce the aggregate quantity and structural stability, which can compact lower layer soil and lead to the development of plow pans [102]. This plow pan formation is not suitable for many crops as it interrupts the roots for proper growth and uptake of water and nutrients from the various depths of the soil. The entire plow pan layer is not compacted by a till, but utilizing low-load machinery enhances pore functioning over time [103].

The ecosystem services that the soil provides can be significantly impacted by changes in the chemical characteristics of the soil. The improvements in soil fertility and pH balance brought about by conservation tillage can be achieved [77, 93, 94]. For the proper growth of plants balancing of pH in the soil should be considered. The chemical features of the soil, such as pH, SOM, nitrogen levels, and exchangeable cations, which are significant from an agricultural perspective, were modified by tillage, residues, and crop rotation [104].

3.2.4. Ability to Sustain Plant Growth. Rhizosphere colonization is crucial for productivity, plant health, and nutrient cycling because rhizosphere microorganisms consume the substrates from plant roots in the soil and live both inside and on them [105]. Rhizobacteria that encourage plant growth successfully colonize the soil around plant roots, increasing nutrient intake, stimulating plant growth, and providing resistance to abiotic stress [106]. By maximizing the variability of the soil microbiota, zero tillage, a technique to minimize soil disturbance, could enhance soil organic matter and improve soil structure, leading to greater aeration and water contents [107]. The exudates produced by a plant's growing roots support a variety of readily utilizable chemical compounds that drive bacterial diversity in the rhizosphere at the blooming stage, which differs from the tillering stage [108]. According to the stability of phylogenetic membership, the individuals in the root microbiota under zero tillage seem to perform identical host tasks for collecting nutrients from the soil to support plant growth [109].

When opposed to conventional tillage, no-till systems typically have more crop roots close to the soil surface, which, upon decomposition, enhanced the availability of nutrients [110]. The ecosystem services that the soil provides can be significantly impacted by changes in the chemical characteristics of the soil [75].

4. Conclusion and Future Planning

A cropping system can be referred to as the method by which various crops are grown, or it might be the order in which they are planted on a plot of land throughout a specific time period. In some cropping systems, various crops are grown in the same field simultaneously or one after the other during brief periods of time. On the other hand, tillage is a substantial input to agricultural activities that alters the soil's chemical, physical, and microbiological composition. The consequences of various soil tillage techniques frequently vary depending on the crop type, location, time of tillage, and past cropping history [111, 112]. At present, population problems and environmental issues are getting worse, while farming practices are getting simpler. Due to this, it is a burning question, how current cropping systems will work in the future in terms of resilience, adaptability to climate change, multifunctionality of the agricultural landscape, supply of ecosystem services, and biodiversity [113]. As the major concern of the modern world is to produce more crops in limited resources of soil so the fertility and biodiversity of soil decrease day by day which induces low crop production in the future. All the ways to increase crop yield as well as maintain soil health are discussed in detail in this review. This review identifies the best suitable cropping system for the individual crops which helps to increase crop production with minimum effect on soil health and also highlights the benefit aspect of conservation tillage compared to conventional tillage to maintain soil fertility. Therefore, more research is currently needed to analyze different tillage methods and develop new cropping systems that will increase the production of various crops and make the future world self-sufficient in food.

Data Availability

This manuscript is a review based on the published articles that are referred and listed in the reference lists of the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

PBA developed the idea. PBA and NA designed the structure. NA, MMA, SKC, and RPS collected the data. PBA, NA, MMA, SKC, RPS, and SJ wrote the manuscript and prepared the final version of the manuscript. PBA revised the manuscript.

References

[1] M. M. Tahat, K. M. Alananbeh, Y. A. Othman, and D. I. Leskovar, "Soil health and sustainable agriculture," *Sustainability*, vol. 12, p. 4859, 2020.

[2] A. Ahmed, J. Kurian, and V. Raghavan, "Biochar influences on agricultural soils, crop production, and the environment: a review," *Environmental Review*, vol. 24, no. 4, pp. 495–502, 2016.

[3] R. Shinde, P. K. Sarkar, N. Thombare, and S. Naik, "Soil conservation: today's need for sustainable development," *Agriculture and Food News*, vol. 1, pp. 175–183, 2019.

[4] P. M. Kopittke, N. W. Menzies, P. Wang, B. A. McKenna, and E. Lombi, "Soil and the intensification of agriculture for global food security," *Environment International*, vol. 132, Article ID 105078, 2019.

[5] S. R. Gliessman, *Agroecosystem Sustainability: Developing Practical Strategies*, CRC Press, Boca Raton, FL, USA, 1 edition, 2000.

[6] H. He, L. Liu, S. Munir et al., "Crop diversity and pest management in sustainable agriculture," *Journal of Integrative Agriculture*, vol. 18, no. 9, pp. 1945–1952, 2019.

[7] X. Ding, M. Yang, H. Huang et al., "Priming maize resistance by its neighbors: activating 1, 4-benzoxazine-3-ones synthesis and defense gene expression to alleviate leaf disease," *Frontiers of Plant Science*, vol. 6, p. 830, 2015.

[8] M. Yang, Y. Zhang, L. Qi et al., "Plant-plant-microbe mechanisms involved in soil-borne disease suppression on a maize and pepper intercropping system," *PLoS One*, vol. 9, no. 12, Article ID e115052, 2014.

[9] J. Somasundaram, R. Chaudhary, D. Awanish Kumar et al., "Effect of contrasting tillage and cropping systems on soil aggregation, carbon pools and aggregate-associated carbon in rainfed vertisols," *European Journal of Soil Science*, vol. 69, no. 5, pp. 879–891, 2018.

[10] C. Terrer, R. P. Phillips, B. A. Hungate et al., "A trade-off between plant and soil carbon storage under elevated CO2," *Nature*, vol. 591, no. 7851, pp. 599–603, 2021.

[11] J. Jin, R. Armstrong, and C. Tang, "Impact of elevated CO2 on grain nutrient concentration varies with crops and soils–A long-term FACE study," *Science of the Total Environment*, vol. 651, pp. 2641–2647, 2019.

[12] P. Sharma, A. Singh, C. S. Kahlon et al., "The role of cover crops towards sustainable soil health and agriculture—a review paper," *American Journal of Plant Sciences*, vol. 9, no. 9, pp. 1935–1951, 2018.

[13] T. Yang, K. H. Siddique, and K. Liu, "Cropping systems in agriculture and their impact on soil health-A review," *Global Ecology and Conservation*, vol. 23, Article ID e01118, 2020.

[14] J. A. Vetsch and G. W. Randall, "Corn production as affected by tillage system and starter fertilizer," *Agronomy Journal*, vol. 94, no. 3, pp. 532–540, 2002.

[15] S. Torabian, S. Farhangi-Abriz, and M. D. Denton, "Do tillage systems influence nitrogen fixation in legumes? A review," *Soil and Tillage Research*, vol. 185, pp. 113–121, 2019.

[16] L. Büchi, M. Wendling, C. Amossé, M. Necpalova, and R. Charles, "Importance of cover crops in alleviating negative effects of reduced soil tillage and promoting soil fertility in a winter wheat cropping system," *Agriculture, Ecosystems & Environment*, vol. 256, pp. 92–104, 2018.
[17] G. F. Botta, D. L. Antille, G. F. Nardon et al., "Zero and controlled traffic improved soil physical conditions and soybean yield under No-tillage," *Soil and Tillage Research*, vol. 215, Article ID 105235, 2022.
[18] T. Shankar, G. C. Malik, M. Banerjee et al., "Productivity and nutrient balance of an intensive rice–rice cropping system are influenced by different nutrient management in the red and lateritic belt of West Bengal, India," *Plants*, vol. 10, no. 8, p. 1622, 2021.
[19] J. Cuevas, I. N. Daliakopoulos, F. del Moral, J. J. Hueso, and I. K. Tsanis, "A review of soil-improving cropping systems for soil salinization," *Agronomy*, vol. 9, no. 6, p. 295, 2019.
[20] M. Bertrand, S. Barot, M. Blouin, J. Whalen, T. de Oliveira, and J. Roger-Estrade, "Earthworm services for cropping systems. A review," *Agronomy for Sustainable Development*, vol. 35, no. 2, pp. 553–567, 2015.
[21] M. A. Busari, S. S. Kukal, A. Kaur, R. Bhatt, and A. A. Dulazi, "Conservation tillage impacts on soil, crop and the environment," *International Soil and Water Conservation Research*, vol. 3, no. 2, pp. 119–129, 2015.
[22] D. S. Peixoto, L. C. M. Silva, L. B. B. Melo et al., "Occasional tillage in No-tillage systems: a global meta-analysis," *Science of the Total Environment*, vol. 745, Article ID 140887, 2020.
[23] E. Vukicevich, T. Lowery, P. Bowen, J. R. Úrbez-Torres, and M. Hart, "Cover crops to increase soil microbial diversity and mitigate decline in perennial agriculture. A review," *Agronomy for Sustainable Development*, vol. 36, no. 3, pp. 48–14, 2016.
[24] J. E. Fargione, S. Bassett, T. Boucher et al., "Natural climate solutions for the United States," *Science Advances*, vol. 4, no. 11, Article ID eaat1869, 2018.
[25] L. A. Stempkowski, F. S. Pereira, J. B. Valente et al., "Management of wheat stripe mosaic virus by crop rotation," *European Journal of Plant Pathology*, vol. 158, no. 2, pp. 349–361, 2020.
[26] S. A. Maarastawi, K. Frindte, M. Linnartz, and C. Knief, "Crop rotation and straw application impact microbial communities in Italian and philippine soils and the rhizosphere of zea mays," *Frontiers in Microbiology*, vol. 9, p. 1295, 2018.
[27] D. Mbodj, B. Effa-Effa, A. Kane et al., "Arbuscular mycorrhizal symbiosis in rice: establishment, environmental control and impact on plant growth and resistance to abiotic stresses," *Rhizosphere*, vol. 8, pp. 12–26, 2018.
[28] M. M. Hossain, M. Begum, A. Hashem et al., "Strip tillage and crop residue retention decrease the size but increase the diversity of the weed seed bank under intensive rice-based crop rotations in Bangladesh," *Agronomy*, vol. 11, no. 6, p. 1164, 2021.
[29] B. Melander, I. A. Rasmussen, and J. E. Olesen, "Legacy effects of leguminous green manure crops on the weed seed bank in organic crop rotations," *Agriculture, Ecosystems and Environment*, vol. 302, Article ID 107078, 2020.
[30] L. Rusinamhodzi, "Managing crop rotations in No-till farming systems," in *No-till Farming Systems for Sustainable Agriculture*, pp. 21–31, Springer, Berlin, Germany, 2020.
[31] M. Jalli, E. Huusela, H. Jalli et al., "Effects of crop rotation on spring wheat yield and pest occurrence in different tillage systems: a multi-year experiment in Finnish growing conditions," *Frontiers in Sustainable Food Systems*, vol. 5, p. 5, 2021.
[32] X. Zheng, B. Koopmann, B. Ulber, and A. von Tiedemann, "A global survey on diseases and pests in oilseed rape—current challenges and innovative strategies of control," *Frontiers in Agronomy*, vol. 2, Article ID 590908, 2020.
[33] S. Maitra and H. Gitari, "Scope for adoption of intercropping system in organic agriculture," *Indian Journal of Natural Sciences*, vol. 11, Article ID 28624, 28631 pages, 2020.
[34] C. Li, T.-J. Stomph, D. Makowski et al., "The productive performance of intercropping," *Proceedings of the National Academy of Sciences*, vol. 120, no. 2, Article ID e2201886120, 2023.
[35] S. Maitra, J. B. Palai, P. Manasa, and D. P. Kumar, "Potential of intercropping system in sustaining crop productivity," *International Journal of Agriculture Environment & Biotechnology*, vol. 12, pp. 39–45, 2019.
[36] H. Eskandari, A. Ghanbari, and A. Javanmard, "Intercropping of cereals and legumes for forage production," *Notulae Scientia Biologicae*, vol. 1, pp. 7–13, 2009.
[37] G. Tosti and M. Guiducci, "Durum wheat–faba bean temporary intercropping: effects on nitrogen supply and wheat quality," *European Journal of Agronomy*, vol. 33, no. 3, pp. 157–165, 2010.
[38] Z. Li, Q. Li, R. Li, J. Zhou, and G. Wang, "The distribution and impact of polystyrene nanoplastics on cucumber plants," *Environmental Science & Pollution Research*, vol. 28, no. 13, 16053 pages, Article ID 16042, 2021.
[39] A. Morugán-Coronado, C. Linares, M. D. Gómez-López, Á. Faz, and R. Zornoza, "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," *Agricultural Systems*, vol. 178, Article ID 102736, 2020.
[40] Q. Cao, D. Yu, M. Georgescu, Z. Han, and J. Wu, "Impacts of land use and land cover change on regional climate: a case study in the agro-pastoral transitional zone of China," *Environmental Research Letters*, vol. 10, no. 12, Article ID 124025, 2015.
[41] O. Gómez-Rodŕıguez, E. Zavaleta-Mej́ia, V. Gonzalez-Hernandez, M. Livera-Munoz, and E. Cárdenas-Soriano, "Allelopathy and microclimatic modification of intercropping with marigold on tomato early blight disease development," *Field Crops Research*, vol. 83, no. 1, pp. 27–34, 2003.
[42] N. L. Hartwig and H. U. Ammon, "Cover crops and living mulches," *Weed Science*, vol. 50, no. 6, pp. 688–699, 2002.
[43] L. E. Drinkwater and S. Snapp, "Nutrients in agroecosystems: rethinking the management paradigm," *Advances in Agronomy*, vol. 92, pp. 163–186, 2007.
[44] B. C. Blaser, J. W. Singer, and L. R. Gibson, "Winter cereal canopy effect on cereal and interseeded legume productivity," *Agronomy Journal*, vol. 103, no. 4, pp. 1180–1185, 2011.
[45] M. Berti, D. Samarappuli, B. L. Johnson, and R. W. Gesch, "Integrating winter camelina into maize and soybean cropping systems," *Industrial Crops and Products*, vol. 107, pp. 595–601, 2017.
[46] J. R. Thiessen Martens and M. H. Entz, "Availability of late-season heat and water resources for relay and double cropping with winter wheat in prairie Canada," *Canadian Journal of Plant Science*, vol. 81, no. 2, pp. 273–276, 2001.
[47] A. Schoeny, S. Jumel, F. Rouault, E. Lemarchand, and B. Tivoli, "Effect and underlying mechanisms of pea-cereal intercropping on the epidemic development of ascochyta

blight," *European Journal of Plant Pathology*, vol. 126, no. 3, pp. 317–331, 2010.
[48] S. S. Snapp, S. M. Swinton, R. Labarta et al., "Evaluating cover crops for benefits, costs and performance within cropping system niches," *Agronomy Journal*, vol. 97, no. 1, pp. 322–332, 2005.
[49] S. C. Cook-Patton, S. H. McArt, A. L. Parachnowitsch, J. S. Thaler, and A. A. Agrawal, "A direct comparison of the consequences of plant genotypic and species diversity on communities and ecosystem function," *Ecology*, vol. 92, no. 4, pp. 915–923, 2011.
[50] N. Mengistu, P. S. Baenziger, L. Nelson et al., "Grain yield performance and stability of cultivar blends vs. Component cultivars of hard winter wheat in Nebraska," *Crop Science*, vol. 50, no. 2, pp. 617–623, 2010.
[51] E. R. Reiss and L. E. Drinkwater, "Cultivar mixtures: a meta-analysis of the effect of intraspecific diversity on crop yield," *Ecological Applications*, vol. 28, no. 1, pp. 62–77, 2018.
[52] R. Manthey and H. Fehrmann, "Effect of cultivar mixtures in wheat on fungal diseases, yield and profitability," *Crop Protection*, vol. 12, no. 1, pp. 63–68, 1993.
[53] A. Newton, "Cultivar mixtures in intensive agriculture," *The gene-for-gene relationship in plant-parasite interactions*, pp. 65–80, Cab International, Wallingford, United Kingdom, 1997.
[54] J. Dai, J. J. Wiersma, and D. L. Holen, "Performance of hard red spring wheat cultivar mixtures," *Agronomy Journal*, vol. 104, no. 1, pp. 17–21, 2012.
[55] R. Whitehair, N. Grudens-Schuck, and L. A. Schulte, "Program evaluation of a workshop on prairie strips for farm advisors: framing the Co-occurring outcomes of low knowledge acquisition and high confidence," *Horticulturae*, vol. 8, no. 12, p. 1215, 2022.
[56] Z. R. Luther, S. M. Swinton, and B. V. Deynze, "Potential supply of midwest cropland for conversion to in-field prairie strips," *Land Economics*, vol. 98, no. 2, pp. 274–291, 2022.
[57] L. A. Schulte, A. L. MacDonald, J. B. Niemi, and M. J. Helmers, "Prairie strips as a mechanism to promote land sharing by birds in industrial agricultural landscapes," *Agriculture, Ecosystems & Environment*, vol. 220, pp. 55–63, 2016.
[58] C. Poeplau and A. Don, "Carbon sequestration in agricultural soils via cultivation of cover crops–A meta-analysis," *Agriculture, Ecosystems & Environment*, vol. 200, pp. 33–41, 2015.
[59] L. A. Schulte, J. Niemi, M. J. Helmers et al., "Prairie strips improve biodiversity and the delivery of multiple ecosystem services from corn–soybean croplands," *Proceedings of the National Academy of Sciences*, vol. 114, no. 42, 11252 pages, Article ID 11247, 2017.
[60] G. P. Robertson, S. K. Hamilton, B. L. Barham et al., "Cellulosic biofuel contributions to a sustainable energy future: choices and outcomes," *Science*, vol. 356, no. 6345, Article ID eaal2324, 2017.
[61] B. P. Werling, T. L. Dickson, R. Isaacs et al., "Perennial grasslands enhance biodiversity and multiple ecosystem services in bioenergy landscapes," *Proceedings of the National Academy of Sciences*, vol. 111, no. 4, pp. 1652–1657, 2014.
[62] R. Lahlali, D. S. Ibrahim, Z. Belabess et al., "High-throughput molecular technologies for unraveling the mystery of soil microbial community: challenges and future prospects," *Heliyon*, vol. 7, no. 10, Article ID e08142, 2021.
[63] G. Lemaire, A. Franzluebbers, P. C. F. Carvalho, and B. Dedieu, "Integrated crop–livestock systems: strategies to achieve synergy between agricultural production and environmental quality," *Agriculture, Ecosystems & Environment*, vol. 190, pp. 4–8, 2014.
[64] D. Jinger, R. Kumar, V. Kakade et al., "Agroforestry for controlling soil erosion and enhancing system productivity in ravine lands of western India under climate change scenario," *Environmental Monitoring and Assessment*, vol. 194, no. 4, p. 267, 2022.
[65] C. Praharaj, U. Singh, S. Singh, and N. Kumar, "Tactical water management in field crops:the key to resource conservation," *Current Science*, vol. 115, no. 7, pp. 1262–1269, 2018.
[66] S. Pandya, T. R. Gadekallu, P. K. R. Maddikunta, and R. Sharma, "A study of the impacts of air pollution on the agricultural community and yield crops (Indian context)," *Sustainability*, vol. 14, no. 20, Article ID 13098, 2022.
[67] B. Rust and J. D. Williams, "How tillage affects soil erosion and runoff," 2010, https://www.ars.usda.gov/ARSUserFiles/20740000/PublicResources/How%20Tillage%20Affects%20Soil%20Erosion%20and%20Runoff.pdf Technical Note.
[68] R. L. Jensen, "The challenge of agricultural consulting," *Bulletin of the Entomological Society of America*, vol. 26, no. 2, pp. 162-163, 1980.
[69] J. He, H. Li, R. G. Rasaily et al., "Soil properties and crop yields after 11 Years of No tillage farming in wheat–maize cropping system in north China plain," *Soil and Tillage Research*, vol. 113, no. 1, pp. 48–54, 2011.
[70] R. Lal, "Soil carbon sequestration and aggregation by cover cropping," *Journal of Soil and Water Conservation*, vol. 70, no. 6, pp. 329–339, 2015.
[71] H. Blanco-Canqui and S. J. Ruis, "No-tillage and soil physical environment," *Geoderma*, vol. 326, pp. 164–200, 2018.
[72] N. Fageria, "Soil quality vs. Environmentally-based agricultural management practices," *Communications in Soil Science and Plant Analysis*, vol. 33, no. 13-14, pp. 2301–2329, 2002.
[73] G. Luo, L. Li, V.-P. Friman et al., "Organic amendments increase crop yields by improving microbe-mediated soil functioning of agroecosystems: a meta-analysis," *Soil Biology and Biochemistry*, vol. 124, pp. 105–115, 2018.
[74] A. Calegari, W. L. Hargrove, D. D. S. Rheinheimer et al., "Impact of long-term No-tillage and cropping system management on soil organic carbon in an oxisol: a model for sustainability," *Agronomy Journal*, vol. 100, no. 4, pp. 1013–1019, 2008.
[75] M. R. Nunes, D. L. Karlen, and T. B. Moorman, "Tillage intensity effects on soil structure indicators—a US meta-analysis," *Sustainability*, vol. 12, no. 5, p. 2071, 2020.
[76] M. Steele, F. Coale, and R. Hill, "Winter annual cover crop impacts on No-till soil physical properties and organic matter," *Soil Science Society of America Journal*, vol. 76, no. 6, pp. 2164–2173, 2012.
[77] L. Lv, Z. Gao, K. Liao, Q. Zhu, and J. Zhu, "Impact of conservation tillage on the distribution of soil nutrients with depth," *Soil and Tillage Research*, vol. 225, Article ID 105527, 2023.
[78] Y. Huang, W. Ren, L. Wang et al., "Greenhouse gas emissions and crop yield in No-tillage systems: a meta-analysis," *Agriculture, Ecosystems & Environment*, vol. 268, pp. 144–153, 2018.
[79] L. Jia, W. Zhao, R. Zhai, Y. An, and P. Pereira, "Quantifying the effects of contour tillage in controlling water erosion in

China: a meta-analysis," *Catena*, vol. 195, Article ID 104829, 2020.

[80] Y. Li, Z. Li, S. Cui, S. Jagadamma, and Q. Zhang, "Residue retention and minimum tillage improve physical environment of the soil in croplands: a global meta-analysis," *Soil and Tillage Research*, vol. 194, Article ID 104292, 2019.

[81] M. Higo, Y. Tatewaki, K. Iida, K. Yokota, and K. Isobe, "Amplicon sequencing analysis of arbuscular mycorrhizal fungal communities colonizing maize roots in different cover cropping and tillage systems," *Scientific Reports*, vol. 10, pp. 1–13, 2020.

[82] A. Williams, M. C. Hunter, M. Kammerer et al., "Soil water holding capacity mitigates downside risk and volatility in US rainfed maize: time to invest in soil organic matter?" *PLoS One*, vol. 11, no. 8, Article ID e0160974, 2016.

[83] S. W. Duiker and D. B. Beegle, "Soil fertility distributions in long-term No-till, chisel/disk and moldboard plow/disk systems," *Soil and Tillage Research*, vol. 88, no. 1-2, pp. 30–41, 2006.

[84] M. Sağlam, K. . Ç. Selvi, O. Dengiz, and F. E. Gürsoy, "Affects of different tillage managements on soil physical quality in a clayey soil," *Environmental Monitoring and Assessment*, vol. 187, pp. 1–12, 2015.

[85] K. Lichter, B. Govaerts, J. Six, K. D. Sayre, J. Deckers, and L. Dendooven, "Aggregation and C and N contents of soil organic matter fractions in a permanent raised-bed planting system in the highlands of Central Mexico," *Plant and Soil*, vol. 305, no. 1-2, pp. 237–252, 2008.

[86] G. Randall and T. Iragavarapu, *Impact of Long-term Tillage Systems for Continuous Corn on Nitrate Leaching to Tile Drainage*, Wiley Online Library, Hoboken, NJ, USA, 1995.

[87] Y. Wang, Y. Zhang, S. Zhou, and Z. Wang, "Meta-Analysis of No-tillage effect on wheat and maize water use efficiency in China," *Science of the Total Environment*, vol. 635, pp. 1372–1382, 2018.

[88] A. Franzluebbers, F. Hons, and D. Zuberer, "Long-term changes in soil carbon and nitrogen pools in wheat management systems," *Soil Science Society of America Journal*, vol. 58, no. 6, pp. 1639–1645, 1994.

[89] A. Roldan, J. Salinas-Garcia, M. Alguacil, and F. Caravaca, "Soil sustainability indicators following conservation tillage practices under subtropical maize and bean crops," *Soil and Tillage Research*, vol. 93, no. 2, pp. 273–282, 2007.

[90] R. Tian, H. Li, H. Zhu, X. Liu, and X. Gao, "Ca2+ and Cu2+ induced aggregation of variably charged soil particles: a comparative study," *Soil Science Society of America Journal*, vol. 77, no. 3, pp. 774–781, 2013.

[91] A. Franzluebbers and F. Hons, "Soil-profile distribution of primary and secondary plant-available nutrients under conventional and No tillage," *Soil and Tillage Research*, vol. 39, no. 3-4, pp. 229–239, 1996.

[92] K. Adhikari and A. E. Hartemink, "Linking soils to ecosystem services—a global review," *Geoderma*, vol. 262, pp. 101–111, 2016.

[93] F. T. De Vries, E. Thébault, M. Liiri et al., "Soil food web properties explain ecosystem services across European land use systems," *Proceedings of the National Academy of Sciences*, vol. 110, no. 35, 14301 pages, Article ID 14296, 2013.

[94] W. Gwenzi, "Rethinking restoration indicators and endpoints for post-mining landscapes in light of novel ecosystems," *Geoderma*, vol. 387, Article ID 114944, 2021.

[95] M. W. Strudley, T. R. Green, and J. Ascoughii, "Tillage effects on soil hydraulic properties in space and time: state of the science," *Soil and Tillage Research*, vol. 99, no. 1, pp. 4–48, 2008.

[96] J. Miriti, G. Kironchi, A. Esilaba, C. Gachene, L. Heng, and D. Mwangi, "The Effects of Tillage Systems on Soil Physical Properties and Water Conservation in a Sandy Loam Soil in Eastern Kenya," *Journal of Soil Science and Environmental Management*, vol. 4, no. 7, pp. 149–154, 2013.

[97] E. Nyakatawa, V. Jakkula, K. Reddy, J. Lemunyon, and B. Norrisjr, "Soil erosion estimation in conservation tillage systems with poultry litter application using RUSLE 2.0 model," *Soil and Tillage Research*, vol. 94, no. 2, pp. 410–419, 2007.

[98] M. A. Arshad, A. J. Franzluebbers, and R. Azooz, "Components of surface soil structure under conventional and No-tillage in northwestern Canada," *Soil and Tillage Research*, vol. 53, no. 1, pp. 41–47, 1999.

[99] K. Rasmussen, "Impact of ploughless soil tillage on yield and soil quality: a scandinavian review," *Soil and Tillage Research*, vol. 53, no. 1, pp. 3–14, 1999.

[100] F. J. A. Pierce, "Systems approach to conservation tillage: introduction," in *A Systems Approach to Conservation Tillage*, pp. 3–14, CRC Press, Boca Raton, FL, USA, 2018.

[101] K. Fabrizzi, F. García, J. Costa, and L. Picone, "Soil water dynamics, physical properties and corn and wheat responses to minimum and No-tillage systems in the southern pampas of Argentina," *Soil and Tillage Research*, vol. 81, no. 1, pp. 57–69, 2005.

[102] H. Zhou, B. Li, and Y. Lu, "Micromorphological analysis of soil structure under No tillage management in the black soil zone of northeast China," *Journal of Mountain Science*, vol. 6, no. 2, pp. 173–180, 2009.

[103] R. Horn, "Time dependence of soil mechanical properties and pore functions for arable soils," *Soil Science Society of America Journal*, vol. 68, no. 4, pp. 1131–1137, 2004.

[104] N. Hulugalle, P. Entwistle, T. Weaver, F. Scott, and L. Finlay, "Cotton-based rotation systems on a sodic vertosol under irrigation: effects on soil quality and profitability," *Australian Journal of Experimental Agriculture*, vol. 42, no. 3, pp. 341–349, 2002.

[105] L. Philippot, J. M. Raaijmakers, P. Lemanceau, and W. H. Van Der Putten, "Going back to the roots: the microbial ecology of the rhizosphere," *Nature Reviews Microbiology*, vol. 11, pp. 789–799, 2013.

[106] Y. Pii, T. Mimmo, N. Tomasi, R. Terzano, S. Cesco, and C. Crecchio, "Microbial interactions in the rhizosphere: beneficial influences of plant growth-promoting rhizobacteria on nutrient acquisition process. A review," *Biology and Fertility of Soils*, vol. 51, no. 4, pp. 403–415, 2015.

[107] F. Borie, R. Rubio, J. Rouanet, A. Morales, G. Borie, and C. Rojas, "Effects of tillage systems on soil characteristics, glomalin and mycorrhizal propagules in a Chilean ultisol," *Soil and Tillage Research*, vol. 88, no. 1-2, pp. 253–261, 2006.

[108] J. M. Chaparro, D. V. Badri, and J. M. Vivanco, "Rhizosphere microbiome assemblage is affected by plant development," *International School of Management Excellence Journal*, vol. 8, no. 4, pp. 790–803, 2014.

[109] D. Bulgarelli, K. Schlaeppi, S. Spaepen, E. V. L. Van Themaat, and P. Schulze-Lefert, "Structure and functions of the bacterial microbiota of plants," *Annual Review of Plant Biology*, vol. 64, no. 1, pp. 807–838, 2013.

[110] R. Qin, P. Stamp, and W. Richner, "Impact of tillage on root systems of winter wheat," *Agronomy Journal*, vol. 96, no. 6, pp. 1523–1530, 2004.

[111] K. E. Giller, J. A. Andersson, M. Corbeels et al., "Beyond conservation agriculture," *Frontiers of Plant Science*, vol. 6, p. 870, 2015.

[112] E. Martínez, J.-P. Fuentes, P. Silva, S. Valle, and E. Acevedo, "Soil physical properties and wheat root growth as affected by No-tillage and conventional tillage systems in a mediterranean environment of Chile," *Soil and Tillage Research*, vol. 99, no. 2, pp. 232–244, 2008.

[113] J. Hufnagel, M. Reckling, and F. Ewert, "Diverse approaches to crop diversification in agricultural research. A review," *Agronomy for Sustainable Development*, vol. 40, no. 2, pp. 14–17, 2020.