Journal of Experimental Agriculture International

Volume 45, Issue 10, Page 337-348, 2023; Article no.JEAI.106696
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Sustainable Soil Utilization and Agriculture Production: Recommendations towards Achieving Sustainability

Banwari Lal Meena [a*], Tarence Thomas [a] and Bahadur Singh Meena [b]

[a] Department of Soil Science and Agricultural Chemistry, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj–211007, U.P., India.
[b] MJRP College of Agriculture & Research, Mahatma Jyoti Rao Phoole University, Jaipur-302019, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2023/v45i102226

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc. are available here: https://www.sdiarticle5.com/review-history/106696

Review Article

Received: 07/08/2023
Accepted: 10/10/2023
Published: 17/10/2023

ABSTRACT

In particular, the nutrient cycle, soil erosion, carbon sequestration, and many different ecological systems are all impacted by current agriculture tactics. Sustainable development's negative environmental and ecological effects can be reduced through organic farming. Utilizing more organic materials in cultivation practices might decrease environmental damage by preserving the natural cycles of the environment's vegetation during the restoration process. Organic farming can also raise food quality. Chemical fertilizers, pesticides, growth hormones, and feed additives for

**Corresponding author: E-mail: banwarilalmeena206@gmail.com;*

farm animals may also be substantially avoided in organic farming. To minimize the constraints and difficult circumstances of natural farming, a combination of organic farming and new technology is of utmost importance. Innovative techniques and cutting-edge ideas are bringing farming systems closer to sustainability while also improving rural productivity and the quality of life for many farmers in a way that is good for the environment. Not only does soil provide food and nutritional support, but it also has many environmental benefits to give. Although it takes centuries to form one millimeter of soil, soil is regarded as a non-renewable resource. The phrase "Soil health" is one of the most frequently used one in agriculture. Agriculture can only continue to be sustainable if the soil is healthy. Numerous issues have put "soil health" in danger, including declining soil fertility, a lack of natural carbon and biodiversity in the soil, salinization, acidification, pollution, and soil erosion and degradation. As stated by FAO, "Soil management is sustainable if it meets the needs of the present without compromising the ability of future generations to meet their own needs."

Keywords: Sustainability; organic farming; soil health; soil; agriculture; production.

1. INTRODUCTION

In terms of crop production, understanding land productive ability or land quality is also a specific notion [1]. The recent expansion of infrastructure and intensification of agriculture have increased the risk of soil erosion and fertility loss without considering the scope of the overall production system [2]. The lithosphere and biosphere system includes soil as one of its parts. The existence of supporting infrastructure and socio-economic improvement depend on this valuable natural resource. One of the most important components of soil is organic matter. An adequate amount of organic carbon or matter in the soil increases soil fertility. The main restrictions on land use are the loss of organic carbon, soil micronutrients, and macronutrients, the eradication of top soil due to erosive processes, the alteration of physical qualities, and the increase in soil salinity [3].

The phrase "soil health" comes from the discovery that crop quality, which is influenced by soil quality, affects both animal and human health [4]. "Soil health, also known as soil quality, is defined as the soil's continuing ability to function as an essential living environment that supports flora, animals, and humans." That a nutritious soil "offers important nutrients for crop growth and development, supports a numerous and energetic biotic community, exhibits a standard soil structure, and enables in the process of undisturbed decomposition" [5] goes beyond the provision of yields is undeniable. Accordingly, the core of organic farming is the restoration of "natural soil fertility" [6]. In a series of publications [7,8, and 9], the idea of soil quality formulated by Larson and Pierce [10] and Doran and Parkin [11] proved highly challenged for being ill-defined and subjective. In order to pass on responsibility for maintaining the soil's quality to the user, the selected recommendation was to talk about soil use rather than soil properties. It had the main objective to increase awareness as well as foster debate among various stakeholders about the value of soil resources [12].

2. QUALITIES OF FERTILE SOIL

- **Ideal soil tilth:** The term "soil tilth" reflects the entire physical configuration of the soil in terms of its efficacy for cultivation of crops. The exact tilth soil lacks large, hard clods and is crumbly, well-structured, black with a high level of organic matter.
- **Enough extent of the soil profile:** The depth of the soil profile through which roots are able to penetrate and search for water and nutrients is referred to as having a sufficient depth. A crop is more likely to be subjected to flooding, disease attack, or drought pressure when the soil has a shallow extent because of a compact layer or previous erosion.
- **Effective drainage and adequate water storage of the soil:** A healthy soil will at sometime during a heavy rain soak up and store more water in medium and small pores, but it will even drain water from large pores more rapidly. Therefore, a healthy soil retains more water for plant uptake throughout the dry periods but may even allow air to quickly circulate back in after rains, encouraging organisms to maintain their ability to thrive.
- **The flow of nutrients that is enough but not excessive:** For a flourishing plant boom and in order to preserve a balanced

cycle of nutrients throughout the system, nutrients must be present in sufficient and accessible proportions. A surplus of nutrients may trigger leaching and capacity for ground water contaminants, excessive nutrient runoff and greenhouse gas losses, as well as toxicity to flora and microbial taxa.

- **Low prevalence of pests and pathogens:** Pests and infections of plants can cause diseases and agricultural damage. The total number of harmful organisms in a healthy soil is limited or extremely less active. This might take place as an outcome of competition across a variety of soil organisms for resources, place of residence, etc. likewise a variety of pests might be better prevented by good plant growth.
- **Significant number of benevolent organisms in the soil:** In order to maintain soil structure, nutrient cycle, break-down of organic matter, suppress plant pests biologically, and many other activities, soil organisms perform an important role. A thriving soil may encourage an enormous and diverse population of beneficial organisms that could carry out these tasks and aid to ensure a healthy soil condition.
- **Limited weed competition:** For water and nutrients which may be necessary for the growth and development of plants, weeds interfere with plants. Weeds may restrict sunlight, disrupt established standing order, harvesting and cultivation operations, and shelter infectious agents and pests that can spread disease.
- **Devoid of contaminants and compounds that could be detrimental:** Healthy soils either don't contain excess levels of hazardous compounds or harmful substances, or they have ability to neutralize or bind them. Due to the soil's richness in persistent organic matter and a wide range of microbial groups, these mechanism makes these harmful substances unavailable to plants.
- **Adaptability and immunity from degradation:** According to Schindelbeck et al. [13], a healthy, well-aggregated soil is adaptable, rich in differed species, and less susceptible to deterioration from wind and rain erosion, further rainfall, severe drought, vehicle compaction, disease outbreak, and other potentially adverse consequences.

3. THE FUNDAMENTALS OF SUSTAINABLE SOIL MANAGEMENT

1. Prevent erosion, stop deforestation, and guard against physical, chemical, and biological soil degradation

Keep up the superior soil quality. Prevent deforestation and limit soil loss, erosion, toxicity, and compaction:

- Endeavor to safeguard the soil.
- Avoid unnecessary soil disturbance, encourage conservation agriculture, no-till, and good soil drainage.
- Select crop patterns that are agro-ecologically and regionally appropriate, and promote crop rotation.
- Use proven strategies to regulate erosion and invest in the advancement of cutting-edge techniques in order to prevent erosion.
- Minimize the chance that any valuables will contaminate the soil.
- Get rid of deforestation and invest in reforestation while allowing our forests to effectively sequester carbon.
- Restrict agricultural activities in physically isolated regions.
- Construct barriers to hinder the spread of deserts, and promote sustainable grazing practices for avoiding overgrazing and degradation.
- Reduce the share of agricultural land that's becoming urbanized.

2. Recover the soils on insignificant, abandoned and degraded areas of land

Improve the trapped, unproductive, commercial, and environmentally valuable resources that may be peripheral or deteriorated lands:

- Carry out the soil and land quality survey.
- Identify the severity of degraded soil, consider the time period that are involved, and thoroughly plan what it will take to restore the soil back to fertility.
- Recover the basic framework of the soil, constantly enhance or stabilize the proportions of soil carbon and organic matter assessed, and fix the durability and existence of the nutrient content.
- Renew the soil to its original boundaries.
- Facilitate holistic system management at the global, national, and local levels.

3. **Preserve the quality, quantity, and ecological services provided by the soil**

Encourage, maintain, and conserve the habitat and environmental services that soil offers and promotes:

- Continue to maintain water and soil.
- Use fertilizers with the ideal consistency, at the perfect period of year, in the optimum amount, and while refusing ecologically fragile fields.
- Nurture and endorse interest in soil's beneficial microbial and biochemical processes.
- Develop immune soils as a foundation for agriculture that is climate-resilient.
- Riparian boundaries and barriers between cultivated land and water reserves were erected.
- Look for appropriate watering approaches that are compatible with the immediate region.
- Conduct "crop viability assessments," "environmental impact assessments," and "excessive preservation significance assessments," particularly when assessing alternate ways to utilize land.

4. **Maximize the productivity of soil within the limits of its inherent potential**

Achieve universal food security by "sustainable intensification," bridging the "yield gap," and replenish the nutrients we remove from the soil:

- Strengthen agricultural systems that are profitable throughout time.
- Implement a holistic approach to bring back nutrients depleted during harvesting crops to regulate soil fertility.
- Accelerate the organic cycle through the application of organic or synthetic mineral fertilizer when required and paying attention to the optimum stability of crop nutrients, both macro and micro.
- Make the best selection of crops according to your region's climate and soil condition.
- Ensure that the residue of the crop protect in situ.
- Keep working with livestock in accordance as an alternative to regulate nutrients.
- Lowered the soil salinity and suitable, precise soil pH.
- Recommend the making use of biochar and pyrolitic stoves among small-scale farmers.

5. **Build knowledge systems, encourage innovation, and strengthen extension services**

To meet the demands of the twenty-first century, revamp our global agricultural extension network:

- Encourage the use of public and private extension offerings and personal zone funds.
- Make sure extension services are primarily directed at women and younger people.
- Offer hands-on instruction to farmers and agribusiness owners.
- Encourage investment in research and development of new, ethically sound, environmentally sound technologies, as well as in better agricultural methods, fertilizers, crop safety systems, seed varieties, and species.
- Study, map, and categorize soils. Taking advantage of current data, provide exact fertilization and control recommendations using crop and soil type.
- Built platforms for exchanging knowledge to advance best practices, make soil data widely accessible, and create long-term soil monitoring infrastructure.
- Enhance proper mechanization without soil compaction.

6. **Explain why soil is important**

For the majority, including business owners, policymakers, farmers, and members of civil society:

- Publicize the significance of soils from an environmental, social, and economic standpoint.
- Encourage partnerships and knowledge sharing between business, academia, government, and civil society to establish an acceptable standard for managing soils, protection, and preservation.
- Provide guidance and training to legislators to help them make rational choices.
- Incorporate an agricultural new education policy in schools which motivate students to choose higher education and a career in agriculture.
- Limit the pressure on the soil that produces so much foodstuffs by guiding everyone every step of the food supply chain—from the end-user to the farmer—on how to cut food waste [14].

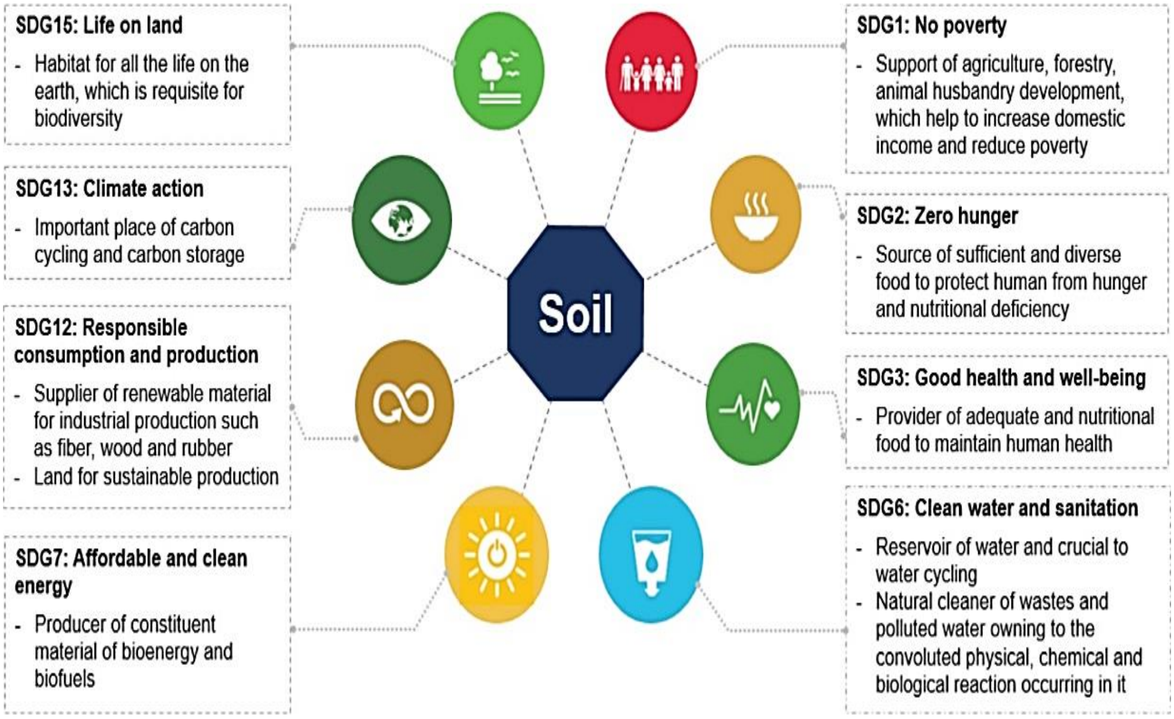

Fig. 1. United Nation's sustainable development goals

4. WHY SHOULD WE PRACTICE SUSTAINABLE AGRICULTURE?

The rate of growth of the global population is high. There are countries in Asia having demographics that are represented in billions, and it is believed that populations across Europe and the Americas are going to reach billions. In the future, this may further exacerbate the desire of individuals for food. Ensuring that everyone has the opportunity to satisfy basic needs in the present and future years serves as one of the most important objectives of commercial agriculture.

Commercial agriculture, on the other hand, consumes more chemicals in order to satisfy growing demand, but performing so contaminates agricultural sources and soil by residues of chemical substances and diminishes production capacity. This actually conflicts itself. Nowadays, the environmentally-conscious farming method assures productivity and a long-term output from agriculture simultaneously saving the soil and the natural world. The positive consequences of sustainable agriculture are primarily listed below:

- ✓ It is quite possible to produce a wide range of goods in restricted spaces with a sustainable agriculture approach.
- ✓ A sustainable firm will have a positive impact on the natural world. While providing a habitat for living things, productive soils contribute as well in the production of agriculture.
- ✓ Similar to the benefits linked to agriculture, fertilization of the soil leads to the emergence of new fields that provide employment and makes sure continuous utilization and boosts productivity [15].

5. DISCUSSION OF MEASURES

1. Landscape structures/refuges to safeguarding biodiversity

In agricultural fields, structural elements may include hedge rows, live fences, shelterbelts, ponds, nonproductive trees, flower strips, buffer strips, perennial timber systems, or stone or terrace walls. In addition to limiting the reduction of organic matter, structural features have also been related to the prevention of wind and water erosion. Advantages of structural features on carbon sequestration, water purification, and retention have also been previously stated, albeit in smaller numbers.

In accordance to studies, structuring elements have an important role in shaping soil biodiversity pools [16]. They are also crucial to habitat connectivity and the reintroduction of taxa that may be discordant with agriculture [17 and 18]. Hedge rows and floral belts are a few instances of linear arrangements which may assist in inhibiting erosion of the soil [19], contribute to debris and nutrient intake in the soil [20], and consequently enhance the quality of water [21]. They may also substantially increase the contents of organic matter and carbon in adjacent agricultural land [22 and 23]. According to Van Den Berge et al. [24] and Grass et al. [25], structural landscape elements are crucial for the natural diversity of agricultural landscapes and thus contribute both directly and indirectly to the soil's flexibility.

While it has been observed that the yield of crops is more reliable and greater resilient to harsh operations on the fields with structural components [26], the total yield is substantially reduced in close proximity to hedge rows whereas it is only somewhat soar at farther distances [27 and 28].

Therefore, more effective funding strategies for structural aspects may also help this approach to gain acceptance more widely. With just slight modifications to management, like retaining adequate distances towards structural features during application of insecticides and fertilizers, it can be simply implemented into existing farming arrangements. Better exchange of information regarding the lasting advantages of distinctly centralize ecosystems for produce stability and endurance can additionally convince growers to think about structural elements with greater confidence.

2. The use of organic fertilizer

To this extent, organic amendments or prolonged usage of organic fertilizer are suggested. This entails the incorporation of biochar, compost, sewage sludge, horn manure, along with additional crop residues, as well as straws and other crop residues, green manure, farmyard manure, solid dung, and compost. Whereas certain participants advocated for using mineral-based fertilizers as a supplementary option, others objected against deploying them at all. In order to contribute to both the enhancement and maintenance of soil endurance and facilitate optimal crop performance, organic fertilizers are being taken into concern.

The use of organic fertilizer and the inclusion of numerous organic materials to the soil have a positive impact on the soil, such as sophisticated biological capabilities, bumped organic carbon, better aggregate balance, more harmonious release of nitrogen fertilizers, lower nitrate leaching, pest and pathogen silence, and upgraded crop yields; especially when used frequently over a longer period of time [29, 30, and 31]. Farmers often have insufficient knowledge of and expertise with bio-based fertilizers, for instance, in respect to the duration of N availability for meeting crop demands [32 and 33]. Despite the fact that organic fertilizers are unquestionably more affordable than mineral fertilizers, Tur-Cardona et al. [34] observed that farmers are far more inclined to go with them. Since the beginning of 2022, the costs of energy have risen significantly, this is making organic fertilizers more attractive to growers. However, farmers often choose reliable versions of nutrients and fertilizers which ensure rapid release of nutrients. Unprocessed manure is typically inexpensive for them, whereas processed organic fertilizers (like digestates) can be obtained in more accessible forms (such as pellets, that's far less odorous) and have been proven that they are high in nutrients.

The anticipated beneficial influence on the state of the soil and its related mutual benefits may serve as an impetus for the execution of this intervention. The option to utilize more organic fertilizer may also encourage farmers that cultivate specific crops to migrate to an integrated approach which involves livestock, which can result in a complete redesign of the farming system [35]. To alleviate farmer misunderstanding over the outcome of organic amendments, further research is required, for example, on the correlation among organic input and diseases, insects, and weeds [36].

3. A variety of approaches to crop rotation

Particular recommendations comprised turning fallow land, grazing on a rotational basis, or cultivated set-aside areas for soil rejuvenation. Further suggestions encompassed a series of foliar and grain plants, cold weather and the summer season vegetation, humus-reducing and humus-improving crops, catch crops, legumes, and deep-rooting plants. Diverse rotations of crops have been associated to a couple of advantages, namely an uptick in agricultural terrain biological diversity and a drop in pest damage. Hence, contaminants in the soil from employing pesticides would be lowered, and more robust crops would emerge. Additionally, erosion control was frequently mentioned with respect to this extent. Ultimately, diverse rotations additionally possess various root networks. This is being taken into consideration to strengthen the structure of the soil, boost fertility rates, minimise the possibility of compactness, assist in the capture of carbon, and keep up the soil's organic matter.

Multiple research studies endorse the beneficial effects of numerous crop cycles on biodiversity in the soil, microbial growth, the structure of the soil, and aggregation, and as a result, on the long-term fertility rates, habitat superiority, erosion threat reduction, and retention of moisture [37, 38, 39, 40, 41, and 42]. Effects, though, are subject to the specific approach. The Rise in retention of carbon, for instance, depend on crop picking, specific to the site variables, and overall management [43 and 44]. The rotation of more than five crops, among which are unique species and farming styles encompassing both summer and winter cereals, tubers and roots, legumes, or set-aside, are widely proposed for lowered application of pesticides and favourable effects on microbial communities in the soil [45 and 46].

Regular crop rotation adoption involves substantial systemic modifications for the vast majority of German farms. Andert et al. [47] urge that, instead of employing control and command mechanisms, more comprehensive details on the pros and cons of diversity in crops, as well as improved planning for both economic and social promotions, should be offered to foster the execution of this level of diversity among German farmers.

4. Proper covering of soil

This can be accomplished using catch crops, under-sown crops, mulching (for instance, agricultural leftovers), and crop rotation that is optimized (by shortening the interval between harvest and sowing of the subsequent crop). Further suggestions for catch crops comprise the use of seed mixtures and ideal seeding times to lower the probability that the crop will not thrive due to pests, diseases, or severe weather (such as dry spells). Likewise skipping row crops, substituting mulch planting for row crops, as well as perennial crops or dense sowing (e.g., opting more dense cereals on winter wheat), was proposed. A prime instance of such would be switching maize by alfalfa or clover grass for the production of biogas. Some of the aforementioned management alternatives proved to have substantial economic limitations, although there was also an opportunity for decreased herbicide use owing to the potential of soil cover to drive down weeds. Generally, consistent soil cover is associated with decreased levels of erosion.

With the goal to minimize the chance of water and wind erosion, soil cover is an essential aspect [48]. The C-factor, regarded as a fairly fundamental parameter that farmers are able to control, is used in the widely used soil loss equation (USLE) to gauge soil cover management [49]. Due to the fact that they effectively wrap the soil throughout the winter, when the soil is normally barren, planting cover crops are especially advantageous. However, they bring extra expenses for farmers (such as added management costs and seed expenses), and implementing them may also call for modifications to the relevant crop rotations [50]. The farmers are possibly missing in specific expertise in this sense [51]. Further, ongoing growth in vegetation will result in an upsurge in overall water need and a reduction in the recharge of groundwater [52]. In order to thoroughly cover the soil, under-sown crops must be sown into the primary crop after it has been planted, even if yields may remain unaffected or even rise [53 and 54]. In conservation tillage systems, covering the soil with crop residue (such as wheat straw) is a regular occurrence. Mulching may boost soil organic matter, lower the demand for fertilizer, elevate soil fertility, and aid to maintain resilient soil ecosystems, based on the type and amount of remains [55 and 56]. However, mulching may additionally enhance the recurrence of diseases which are transmitted by residues [57]. As a result of persisted changes in the climate, this problem is projected to get worse [58].

It also necessitates systemic adjustment to enforce the exclusive soil cover management approaches. The rotations may also need to be adjusted for vegetation cover, while identical crops need to be selected for the pair of under-sown crops and specialized tools, such as for combined harvesting and sowing, may be desired [59]. In areas wherever water is a limiting aspect, mulching may be preferred to stable cover of foliage. Various crop rotations may be desirable in this case to avert excessive pest pressure, as suggested by Buhre et al. [60]. Farmers should also think about upgrading to conservation tillage tactics.

5. The use of conservation tillage

In order to lessen the physical disturbance of the soil, conservation tillage tactics replace conventional ploughing with mulch planting process, strip-tilling, or seeding directly. The aforementioned steps were meant to raise the soils' ability to cope with pressure, stimulate carbon sequestration, cut the loss of water, increase the activity of organisms, inhibit erosion, compaction, and capping, and lower NO^{-}_3 losses. On how to deal with the higher levels of weed burden generated through plowless mechanisms, evaluations differed.

Although benefits vary based on the characteristics of the soil as well as management, conservation tillage strategies may boost soil wearing capacity and prevent soil compaction [61 and 62]. Conversely, transitioning from conventional to conservation tillage may result in greater compaction, for example, when crop rotations are unable to involve crops with deep roots and when the circumstances for earthworm bioturbation are adverse [63]. Dimassi et al. [64] reveal that reduced tillage approaches employed during humid, warm conditions lead to a net decline in the soil organic carbon store within the entire soil profile. Although the reserves of carbon are increased, the climatic rewards may be nullified by additional N_2O emissions [65 and 66]. Additionally, it has been demonstrated that conservation tillage techniques limit soil erosion [67]. The compromises with weed pressure typically result in obstacles to implementation. When extensive-spectrum chemicals are adopted in conjunction with conservation tillage practices, wages as well as operational costs decrease because mechanical weed control through plowing no longer takes place [68]. However, the impact on biodiversity of soil may be either beneficial or detrimental focused on the invertebrate, microbial, and fungal taxa involved [69, 70, 71, and 72].

When weeds are controlled with broad-spectrum herbicides, conservation tillage procedures can be carried out without major systemic alterations. However, they do require specific machinery and definitely particular sequencing of agricultural activities. The successful execution of conservation tillage implies a high quality of supervisors, that involves meticulous selection of crops and rotations appropriate to the specific conditions of the soil and the climate of the area [73], indicating a significant systemic shift. As suggested by Nabel et al. [74], using a broad-spectrum pesticide during mulch seeding should be avoided. If every other approach of controlling pests proves not successful, tillage may be employed. In this situation, they advise adding natural supplements right once to make up for the carbon losses brought on by the tillage and allow for a quick faunal recovery.

6. SUMMARY

By the year 2050, it is expected that there will be nine billion people on the planet, up from the current 7.7 billion. Meanwhile, expanding urban areas and changing climates force out agricultural land. As per the World Bank, by the year 2050, production of food must rise approximately 70% for creating the difference. A key aspect of the way forward to fed more people while mitigating the impact of climate change is agricultural sustainability. Each of the objectives can be achieved by transitioning to an ecologically sound method for producing food as well as fiber. The term sustainable agricultural aim to safeguard the ecosystem, augment the biodiversity of our planet, and keep and enhance soil fertility. A shift from modern commercialized food systems to sustainable agriculture can, in the long term, be quite optimistic for the world that is tormented by disasters and challenges with demand for energy. Considering the fact that the modern agricultural sector generates plenty of opportunities for farmers and offers a lot of food throughout the cropping season, it additionally presents a number of serious concerns that need to be rectified with adoption of methods that are sustainable.

7. CONCLUSION

Most of the measures have more than one gain, and some of them tackle various hazards or aspects. Fortunately, if they are to be implemented, these steps demand to different levels of transformation in the agricultural sector, something is particularly important given that the remedies should ideally be synchronized. One of the basic necessities for more environmentally friendly soil management is heterogeneity. The findings we obtained reflect the generally accepted evidence that a range of practices and cropping systems is the most efficient way for safeguarding and restoring soil health and address the projected needs of supply and demand and climate change.

ACKNOWLEDGEMENTS

I am grateful for ever-inspiring guidance, constant encouragement and scholarly comments and constructive suggestions throughout the course of my studies and investigation, from, head of the department and staff, Department of Soil Science and Agricultural Chemistry, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Dengiz, O. and Saglam, M. Determination of land productivity index based on parametric approach using GIS technique. Eura. J. Soil Sci. 2012;1:51-57.
2. Singh SK, Kumar Mahesh, Sharma BK, Tarafdar JC. Depletion of Organic carbon, phosphorus and potassium stock under pearl millet based cropping sequence in arid environment of India. Arid land Research and Management. 2007;21:119-131.
3. Kumar M, Yadav SR, Gulati IJ. Evaluation of soil status in Sriganganagar district of Rajasthan. International Journal of Chemical Studies. 2017;5(4): 776-780.
4. Warkentin, B.P. The changing concept of soil quality. Journal of Soil and Water Conservation. 1995;50(3):226-228.
5. Mader P, Fliessbach A, Dubois D, Gunst L, Fried P, Niggli U. Soil fertility and biodiversity in organic farming. Science. 2002;296(5573):1694-1697.
6. Rusch HP, Bodenfruchtbarkeit: eine Studie biologischen Denkens. Karl F. Haug Verlag, Heidelberg; 1985.
7. Letey J, Sojka RE, Upchurch DR, Cassel DK, Olson KR, Payne WA, Petrie SE, Price GH, Reginato RJ, Scott HD, Smethurst PJ, Triplett GB. Deficiencies in the soil quality concept and its application. Journal of Soil and Water Conservation. 2003;58(4):180-187.
8. Sojka RE, Upchurch DR. Reservations regarding the soil quality concept. Soil Science Society of America Journal. 1999;63(5):1039-1054.
9. Sojka RE, Upchurch DR, Borlaug NE. Quality soil management or soil quality soil management: Performance versus semantics. in: Advances in Agronomy. (Ed.) D.L. Sparks. 2003;79:1-68.
10. Larson WE, Pierce FJ. Conservation and enhancement of soil quality. in: Evaluation for sustainable land management in the developing world. IBSRAM proceedings, Technical papers. Bangkok, Thailand. 1991;12(2):175-203.
11. Doran JW, Parkin TB. Defining and Assessing Soil Quality. in: Defining Soil Quality for a Sustainable Environment. (Eds.) J.W. Doran, D.C. Coleman, D.F. Bezdicek, B.A. Stewart, SSSA., Madison, WI. 1994;35:3-21.
12. Karlen DL, Andrews SS, Doran JW. Soil quality: Current concepts and applications. Advances in Agronomy. 2001;74: 1-40.
13. Schindelbeck, Robert, Ristow, Aaron, Kurtz, Kirsten, Fennell, Lindsay and Van Es, Harold. What Is Soil Health? in: Developing Healthy Landscapes, Soil Health. 2020;3.
14. United Nation Global Compact. Principles for sustainable soil management. 2016;1-8.
15. Tuğrul, Koç Mehmet. Soil management in sustainable agriculture. IntechOpen. 2019:*88319*: 03
16. Barthel S, Crumley CL, Svedin U. Biocultural refugia: combating the erosion of diversity in landscapes of food production. Ecol Soc. 2013:18(4): *71*
17. Grass I, Loos J, Baensch S, Batáry P, Librán-Embid F, Ficiciyan A, Klaus F, Riechers M, Rosa J, Tiede J, Udy K, Westphal C, Wurz A, Tscharntke T. Land-sharing sparing connectivity landscapes for ecosystem services and biodiversity conservation. People and Nature. 2019;1(2):262–272.
18. Savić B, Evgrafova A, Donmez C, Vasić F, Glemnitz M, Paul C. Assessing the role of kettle holes for providing and connecting amphibian habitats in agricultural landscapes. Land. 2021;10(7): 692.
19. Marshall E, Moonen A. Field margins in northern Europe: their functions and interactions with agriculture. Agric Ecosyst Environ. 2002;89(1–2): 5–21.
20. Garratt MPD, Senapathi D, Coston DJ, Mortimer SR, Potts SG. The benefits of hedgerows for pollinators and natural enemies depends on hedge quality and landscape context. Agric Ecosyst Environ. 2017;247:363–370.

21. Tamburini G, Bommarco R, Wanger TC, Kremen C, van der Heijden MGA, Liebman M, Hallin S. Agricultural diversification promotes multiple ecosystem services without compromising yield. Sci Adv. 2020;6(45).
22. Van Vooren L, Reubens B, Broekx S, de Frenne P, Nelissen V, Pardon P, Verheyen K. Ecosystem service delivery of agri-environment measures: A synthesis for hedgerows and grass strips on arable land. Agric Ecosyst Environ. 2017;244:32–51.
23. Wojewoda D, Russel S. The impact of a shelterbelt on soil properties and microbial activity in an adjacent crop field. Pol J Ecol. 2003;51(3): 291–307.
24. Van Den Berge S, Baeten L, Vanhellemont M, Ampoorter E, Proesmans W, Eeraerts M, Hermy M, Smagghe G, Vermeulen I, Verheyen K. Species diversity, pollinator resource value and edibility potential of woody networks in the countryside in northern Belgium. Agric Ecosyst Environ. 2018;259:119–126.
25. Grass I, Loos J, Baensch S, Batáry P, Librán-Embid F, Ficiciyan A, Klaus F, Riechers M, Rosa J, Tiede J, Udy K, Westphal C, Wurz A, Tscharntke T. Land-sharing sparing connectivity landscapes for ecosystem services and biodiversity conservation. People and Nature. 2019; 1(2): 262–272.
26. Redhead JW, Oliver TH, Woodcock BA, Pywell RF. The influence of landscape composition and configuration on crop yield resilience. J Appl Ecol. 2020;57:2180–2190.
27. Raatz L, Bacchi N, Walzl KP, Glemnitz M, Muller MEH, Joshi J, Scherber C. How much do we really lose yield? losses in the proximity of natural landscape elements in agricultural landscapes. Ecol Evol. 2019;9(13):7838–7848.
28. Van Vooren L, Reubens B, Broekx S, de Frenne P, Nelissen V, Pardon P, Verheyen K. Ecosystem service delivery of agri-environment measures: A synthesis for hedgerows and grass strips on arable land. Agric Ecosyst Environ. 2017;244: 32–51.
29. Bailey KL, Lazarovits G. Suppressing soil-borne diseases with residue management and organic amendments. Soil Tillage Res. 2003;72(2):169–180.
30. Crystal-Ornelas R, Thapa R, Tully KL. Soil organic carbon is affected by organic amendments, conservation tillage, and cover cropping in organic farming systems: A meta-analysis. Agric Ecosyst Environ. 2021;312:107356.
31. Diacono M, Montemurro F. Long-term effects of organic amendments on soil fertility. In: Lichtfouse E, Hamelin M, Navarrete M, Debaeke P (eds), Sustainable agriculture. Springer Netherlands. 2011;2:761-786.
32. Tur-Cardona J, Bonnichsen O, Speelman S, Verspecht A, Carpentier L, Debruyne L, Marchand F, Jacobsen BH, Buysse J. Farmers' reasons to accept bio-based fertilizers: A choice experiment in seven different European countries. J Clean Prod. 2018;197:406–416.
33. Sanchez JE, Harwood RR, Willson TC, Kizilkaya K, Smeenk J, Parker E, Paul EA, Knezek BD, Robertson GP. Managing soil carbon and nitrogen for productivity and environmental quality. Agron J. 2004;96(3): 1.
34. Tur-Cardona J, Bonnichsen O, Speelman S, Verspecht A, Carpentier L, Debruyne L, Marchand F, Jacobsen BH, Buysse J. Farmers' reasons to accept bio-based fertilizers: A choice experiment in seven different European countries. J Clean Prod. 2018;197:406–416.
35. Wezel A, Casagrande M, Celette F, Vian J-F, Ferrer A, Peigné J. Agroecological practices for sustainable agriculture. A Review. Agron Sustain Dev. 2014;34(1): 1–20.
36. Hijbeek R, Pronk AA, van Ittersum MK, Verhagen A, Ruysschaert G, Bijttebier J, Zavattaro L, Bechini L, Schlatter N, ten Berge HFM. Use of organic inputs by arable farmers in six agro-ecological zones across Europe: Drivers and barriers. Agric Ecosyst Environ. 2019:275: 42–53
37. Ayalew DA, Deumlich D, Šarapatka B. Agricultural landscapescale C factor determination and erosion prediction for various crop rotations through a remote sensing and GIS approach. Eur J Agron. 2021;123:126203.
38. D'Acunto L, Andrade JF, Poggio SL, Semmartin M. Diversifying crop rotation increased metabolic soil diversity and activity of the microbial community. Agric Ecosyst Environ. 2018;257:159-164.
39. Kay BD. Rates of change of soil structure under different cropping systems. In: Stewart BA (ed), Advances in soil science. Springer, New York. 1990;1-52.
40. Kollas C, Kersebaum KC, Nendel C, Manevski K, Müller C, Palosuo T, Armas-

Herrera CM, Beaudoin N, Bindi M, Charfeddine M, Conradt T, Constantin J, Eitzinger J, Ewert F, Ferrise R, Gaiser T, Cortazar-Atauri IGd, Giglio L, Hlavinka P, Hoffmann H, Hoffmann MP, Launay M, Manderscheid R, Mary B, Mirschel W, Moriondo M, Olesen JE, Öztürk I, Pacholski A, RipocheWachter D, Roggero PP, Roncossek S, Rötter RP, Ruget F, Sharif B, Trnka M, Ventrella D, Waha K, Wegehenkel M, Weigel H-J, Wu L. Crop rotation modelling—a European model intercomparison. Eur J Agron. 2015;70:98–111.

41. Munkholm LJ, Heck RJ, Deen B. Long-term rotation and tillage effects on soil structure and crop yield. Soil Tillage Res. 2013;127:85-91.
42. Tiemann LK, Grandy AS, Atkinson EE, Marin-Spiotta E, McDaniel MD. Crop rotational diversity enhances belowground communities and functions in an agro ecosystem. Ecol Lett. 2015;18(8): 761–771.
43. FAO, ITPS. Recarbonizing global soils: a technical manual of recommended management practices. Cropland, grassland, integrated systems and farming approaches- practices overview. 2021;3.
44. Scheffler M, Wiegmann K. Quantifizierung von Maßnahmenvorschlägen der deutschen Zivilgesellschaft zu THG - Minderungspotenzialen in der Landwirtschaft bis 2030 [Kurzstudie im Auftrag der Klima-Allianz Deutschland]. Öko-Institut e.V; 2019.
45. Andert S, Bürger J, Stein S, Gerowitt B. The influence of crop sequence on fungicide and herbicide use intensities in North German arable farming. Eur J Agron. 2016:77: 81-89.
46. Tiemann LK, Grandy AS, Atkinson EE, Marin-Spiotta E, McDaniel MD. Crop rotational diversity enhances belowground communities and functions in an agroecosystem. Ecol Lett. 2015;18(8): 761–771.
47. Andert S, Bürger J, Stein S, Gerowitt B. The influence of crop sequence on fungicide and herbicide use intensities in North German arable farming. Eur J Agron. 2016;77:81- 89.
48. Deumlich D, Funk R, Frielinghaus M, Schmidt W-A, Nitzsche O. Basics of effective erosion control in German agriculture. J Plant Nutr Soil Sci. 2006:169(3): 370–381.
49. Auerswald K, Ebertseder F, Levin K, Yuan Y, Prasuhn V, Plambeck NO, Menzel A, Kainz M. Summable C factors for contemporary soil use. Soil Tillage Res. 2021;213:105155.
50. Sattler C, Nagel UJ. Factors affecting farmers' acceptance of conservation measures- a case study from north-eastern Germany. Land Use Policy. 2010;27(1): 70–77.
51. Werner M, Wauters E, Bijttebier J, Steinmann H-H, Ruysschaert G, Knierim A. Farm level implementation of soil conservation measures: farmers' beliefs and intentions. Renew Agric Food Syst. 2017;32(6):524 – 537.
52. Lischeid G, Natkhin M. The potential of land-use changes to mitigate water scarcity in Northeast Germany – a Review. Erde1. 2011;42:97–113.
53. Bergkvist G, Stenberg M, Wetterlind J, Båth B, Elfstrand S. Clover cover crops under-sown in winter wheat increase yield of subsequent spring barley—effect of N dose and companion grass. Field Crops Res. 2011;120(2): 292–298.
54. Johnson KL, Kandel HJ, Samarappuli DP, Berti MT. Inter seeding camelina and rye in soybean with varying maturity provides soil cover without affecting soybean yield. Agron. 2021;11(2): 353.
55. Kollas C, Kersebaum KC, Nendel C, Manevski K, Müller C, Palosuo T, Armas-Herrera CM, Beaudoin N, Bindi M, Charfeddine M, Conradt T, Constantin J, Eitzinger J, Ewert F, Ferrise R, Gaiser T, Cortazar-Atauri IGd, Giglio L, Hlavinka P, Hoffmann H, Hoffmann MP, Launay M, Manderscheid R, Mary B, Mirschel W, Moriondo M, Olesen JE, Öztürk I, Pacholski A, RipocheWachter D, Roggero PP, Roncossek S, Rötter RP, Ruget F, Sharif B, Trnka M, Ventrella D, Waha K, Wegehenkel M, Weigel H-J, Wu L. Crop rotation modelling—a European model intercomparison. Eur J Agron. 2015;70:98–111.
56. Tiemann LK, Grandy AS, Atkinson EE, Marin-Spiotta E, McDaniel MD. Crop rotational diversity enhances belowground communities and functions in an agroecosystem. Ecol Lett. 2015:18(8): 761–771.
57. Koivunen EE, Tully KL, Swett CL. Co-managing soil and plant pathogens: Effects of organic amendments on soil fertility and

fungal pathogen survival. Plant Soil. 2018;432(1):171–189.
58. Fareed Mohamed Wahdan S, Hossen S, Tanunchai B, Schädler M, Buscot F, Purahong W. Future climate significantly alters fungal plant pathogen dynamics during the early phase of wheat litter decomposition. Microorganisms. 2020;8(6): 908.
59. Sattler C, Nagel UJ. Factors affecting farmers' acceptance of conservation measures- A case study from north-eastern Germany. Land Use Policy. 2010;27(1):70–77.
60. Buhre C, Kluth C, Bürcky K, Märländer B, Varrelmann M. Integrated control of root and crown rot in sugar beet: Combined effects of cultivar, crop rotation, and soil tillage. Plant Dis. 2009;93(2):155–161.
61. Mirzavand J, Moradi-Talebbeigi R. Relationships between field management, soil compaction, and crop productivity. Arch Agron Soil Sci. 2021;67(5):675–686.
62. Pöhlitz J, Rücknagel J, Koblenz B, Schlüter S, Vogel H-J, Christen O. Computed tomography and soil physical measurements of compaction behaviour under strip tillage, mulch tillage and no tillage. Soil Tillage Res. 2018;175:205–216.
63. Schlüter S, Großmann C, Diel J, Wu G-M, Tischer S, Deubel A, Rücknagel J. Long-term effects of conventional and reduced tillage on soil structure, soil ecological and soil hydraulic properties. Geoderma. 2018;332:10–19.
64. Dimassi B, Mary B, Wylleman R, Labreuche J, Couture D, Piraux F, Cohan J-P. Long-term effect of contrasted tillage and crop management on soil carbon dynamics during 41 years. Agric Ecosyst Environ. 2014;188:134–146.
65. Guenet B, Gabrielle B, Chenu C, Arrouays D, Balesdent J, Bernoux M, Bruni E, Caliman J-P, Cardinael R, Chen S, Ciais P, Desbois D, Fouche J, Frank S, Henault C, Lugato E, Naipal V, Nesme T, Obersteiner M, Pellerin S, Powlson DS, Rasse DP, Rees F, Soussana J-F, Su Y, Tian H, Valin H, Zhou F. Can N2O emissions offset the benefits from soil organic carbon storage? GlobChang Biol. 2021;27(2):237–256.
66. Mei K, Wang Z, Huang H, Zhang C, Shang X, Dahlgren RA, Zhang M, Xia F. Stimulation of -N2O emission by conservation tillage management in agricultural lands: A meta-analysis. Soil Tillage Res. 2018;182: 86–93.
67. Seitz S, Goebes P, Puerta VL, Pereira EIP, Wittwer R, Six J, van der Heijden MGA, Scholten T. Conservation tillage and organic farming reduce soil erosion. Agron Sustain Dev. 2018;39(1):4.
68. Mal P, Schmitz M, Hesse JW. Economic and environmental effects of conservation tillage with glyphosate Use: a Case Study of Germany. Outlooks Pest Manag. 2015;26(1): 24–27.
69. Chávez-Ortiz P, Tapia-Torres Y, Larsen J, García-Oliva F. Glyphosate-based herbicides alter soil carbon and phosphorus dynamics and microbial activity. Appl Soil Ecol. 2022;169: 104256.
70. Froslev TG, Nielsen IB, Santos SS, Barnes CJ, Bruun HH, Ejrnaes R. The biodiversity effect of reduced tillage on soil microbiota. Ambio. 2022;51(4):1022–1033.
71. Van Capelle C, Schrader S, Brunotte J. Tillage-induced changes in the functional diversity of soil biota — a review with a focus on German data. Eur J Soil Biol. 2012;50:165–181.
72. Zaller JG, Heigl F, Ruess L, Grabmaier A. Glyphosate herbicide affects belowground interactions between earthworms and symbiotic mycorrhizal fungi in a model ecosystem. Sci Rep. 2014;4(1):5634.
73. Peigné J, Ball BC, Roger-Estrade J, David C. Is conservation tillage suitable for organic farming? A Review. Soil Use Manag. 2007;23(2):129–144.
74. Nabel M, Selig C, Gundlach J, von der Decken H, Klein M. Biodiversity in agricultural used soils: threats and options for its conservation in Germany and Europe. Soil Org. 2021;93(1):1-11

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/106696