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SUSTAINABLE AGRONOMIC PRACTICES FOR SOIL CONSERVATION AND CLIMATE CHANGE MITIGATION IN INDIA

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ABSTRACT

This present review paper focuses on the safe and ecological practices that are essential in maintaining the life and mitigate the effects of climate change in Indian agriculture sector. In the paper the author considers specifics of such practices as contour ploughing, terracing, and cover cropping which are vital in preventing the erosion of the soil and improving its structure and fertility. Additionally, it presents the essentiality of conservation tillage, organic farming, and integrated soil fertility management (ISFM) as fundamental process practices for carbon stocks accumulation, greenhouse gases mitigation, and nutrients use efficiency enhancement. The review integrates existing literature to demonstrate that those practices that enhance the various aspects of soil shown above to be beneficial on productivity have beneficial effects on the soil as well: for example, organic carbon content, nutrient replenishment status, and microbial function. But it also comprises the economic, educational, and policy conditions limiting the application of sustainable ideas. In practice, the paper provides examples of the described practices at the regional level and explains the improvements that has been achieved in the context of various Indian states. In the paper's conclusion, recommendations for future research are provided with a focus on the lasting effects and development of sustainable practices and policy actions to improve the rates of sustainability practice adoption such as grants/credits for financial incentives and educational courses. Thus, in the context of increasing soil degradation and climate change challenges, the review launched a call for the promotion of sustainable agronomic practices in limited access Indian agriculture.

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INTRODUCTION

The challenges of climatic changes have been pressing in India, and, therefore, there is a demand to adopt sustainable agronomic practices with soil conservation and climate change mitigation as the central point. The extensive agricultural practices are the cause for the drastic soil deterioration; this includes soil erosion, nutrient depletion, and loss of organic matter. Such circumstances severely affect the productivity and sustainability of the farming systems (Sharma, Shah, & Roy, 2012). Conservation Agriculture (CA) has become a radical new approach to soil management by removing the use of traditional ploughing, ensuring the soil is kept covered, and diversifying the cropping schemes. This innovative technique has shown satisfactory results in improving soil health, the water and nutrient use efficiency while tackling problems arising due to the climate (Yogesh, Kumar, & Singh, 2020).

Soil conservation is not the only role of CA, but the latter also is actively involved in climate change mitigation. Zero tillage and Mulching are the two methods which are used by CA to slow to occur soil erosion, enhance soil water holding capacity, and thus, amplify farm productivity. The fact that CA practices also help in carbon sequestration, thus, contributing to the mitigation of greenhouse gas emissions and balance the atmospheric CO2 levels. at the same time. (Bhattacharyya, Jha, & Kumar, 2023) Additionally, alongside CA, some other agronomic practices for crop cultivation have shown their potential such as strip cropping, intercropping, and agroforestry. These methods are not only protection of the soil from erosion and enhancement of soil fertility but also, they allow water conservation and show of biodiversity (Misebo, 2018).

Despite the proven benefits of such environmentally friendly practices, the application of these methods in India is not without difficulties. Obstacles like the insufficient distribution of advance agriculture tools, deficient infrastructure, and lack of awareness among the smallholder farmer community lead to the following effects the widespread immersion of these methods. Addressing the said problems is very important to the drive for sustainable agriculture and the making of the country into a better climate adapted area. This paper endeavors to delve into the different sustainable agronomic practices utilized in India, evaluate their efficacy strategies for soil conservation and climate change that are available, and also propose solutions to the problems for them to be widespread.

This critique strives to give a whole explanation of sustainable agronomic practices in India, with a focus on soil conservation and climate change mitigation. The focal point is to spot a variety of sustainable agronomic strategies that have been implemented nationwide, evaluating their effectiveness in solving the most important issues, for instance, soil erosion, soil fertility, and the

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overall health of the soil. A better grasp of the different tactics employed allows approximately the authors to say how these strategies could be halted from making soil unproductive and make farming more efficient. As well as this, the review will question if such sustainable activities lead to the transition from pollution to no pollution, including their role in carbon sequestration and gas emission reductions. A defining aspect of the review will be the delineation of the hitches and stumbling blocks that stop the worldwide application of such processes and the formulation of suggestions aimed at the elimination of these bottlenecks. The final part of the paper will present success stories and renewed methods that have showed positive results and therefore can be replicated in different regions of India and even more widely. The paper will aggregate current research and practical knowledge to drive reflective thinking on how best to use sustainable agronomic practices for the protection of soil cover and combat climate change in India.

SOIL CONSERVATION IN INDIAN AGRICULTURE

Soil conservation is the most important component of sustainable agriculture and it is particularly important in a country like India where the soil health and fertility and productivity are greatly affected by many different climatic conditions and different landforms. The introduction of more effective strategies of soil conservation is of the utmost importance to foster the maintenance of soil fertility, halt change to the appearance of the land and promote the sustainability of the land. This segment discusses the major soil management technologies used in the Indian agricultural system, which are related to talking about erosion control, cover crops, and trees in farm systems.

EROSION CONTROL

Soil erosion is the main issue of concern in Indian agriculture, especially in the areas of hills and cliffs. Soil Loss will occur if water erodes. Several practices have been developed to control erosion and preserve soil health:

1. **Contour Plowing:** This is a system where the plough line is made following the contour lines of the slope. This technique is useful to hold the water and reduce the speed of runoff as well as erosion of soil. By erecting natural obstacles to water flow, contour plowing serves also to keep the soil formations and humidity to the optimal level. Research by Sharma et al. (2012) underlined the effectiveness of contour plowing in preventing the soil erosion and invigorating the soil strength in varied Indian territories.
2. **Terracing:** Terracing involves digging series of flat surfaces along the steep gradient in order to ease water drainage and hold back soil. It is a method that is commonly used in the mountainous regions of India. Such case studies are the Western Ghats and the Himalayan Foothills. Moreover, Bhattacharyya et al. (2023) refer how alongside physical stabilization, weakening of loosening of soil thus increasing agriculture is practiced by terracing.

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3. **Strip Cropping:** This is a common modern agricultural practice done on the land, which is just traveling the period of a year, and then it is possible to make changes to the crops or vegetation in order to achieve a number of beneficial effects. Strip cropping reduces soil erosion by impeding water runoff and improving soil infiltration. In their studies, strip cropping (Yogesh et al., 2020) is known to have proven successful in districts based in India, particularly in zones that have been affected by gully erosion which is the case with the Uttar Pradesh and Bihar regions.

COVER CROPS

Such cover crops as legumes and grasses, contribute to the sustainability of the soil and erosion prevention. These particular plants have been cultivated to protect and cover the soil, the main purpose being soilcover rather than harvest to get the result of:

1. Soil Structure Improvement: Cover crops through the addition of organic matter to the soil, thus, become the catalyst for soil improvement. The organic matter also improves soil aggregation, increases water infiltration, and lessens compaction. (Misebo et al 2018) provides examples of how legumes, such as pigeon pea and chickpea, improve soil structure and fertility in Indian agricultural systems.
2. Erosion Prevention: The reason why cover crops keep the soil safe is that they shield directly from the impact of the rain, thus preventing water from distributing, the risk of erosion is minimized. Root systems ensure that the soil is kept in an upright position. Cover crop use such as the ones that are applied in rye and mustard according to the cover crop case studies from different Indian regions have led to significant improvements in conservation practices, e.g., in the case of (Sharma et al. 2012).
3. Case Studies: The use of cover crops is successful in several regions including Punjab and Haryana, where heavy use of soil and water-intensive farming practices are becoming the leading cause of soil health deterioration. Research by (Yogesh et al., 2020) proposes that the application of cover crops could help to uphold the soil in good health and thus lead to hyped up crop productivity in these areas.

AGROFORESTRY

Agroforestry is the mingling of trees and shrubs among crops and/or livestock. It is a multi-layered system which not only gives the soil conservation as well as the utility of a lot of other more:

- Reducing Soil Erosion: Early windbreaks agroforestry has proven its worth in soil erosion control. Herbaceous species are excellent for fixing nitrogen and taking up its leaching to the deeper layers and, thus, are crucial for improving the soil structure and fertility. Agroforestry systems that combine lucrative tree poplar species, like GreenRiv (Populus x

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can.) and weeping willow (Salix babylonica), and groundnut intercrops have been found to be more productive overall. Bhattacharyya et al. have stressed the fact that according to the year of 2023 agroforestry deals with soil erosion and it's a great help especially in semi-arid India.

- Improving Soil Fertility: Soil fertility can be increased with organic material from the tree branches and leaves, which provides nutrients by breaking down, as well as increased soil organic matter. Agroforestry systems promote soil quality and productivity. Misebo (2018) underscores the plentiful agroforestry projects in India like neem-trees and teak beside the crops. It made remarkable strides in the area of soil fertility.
- Successful Projects: Tree-based farming, on the other hand, seems to be more accepted by the community, as it has been found to protect the soil and increase productivity. Trees manage to ameliorate many aspects i.e. water, soil health, and nutrients. The growing need of wood, the main raw material for paper and furniture besides providing employment, is met through the sustainable use of forest and tree resources. The projects have served as catalysts for reviving soil health and for the setting up of more resilient agricultural systems (Yogesh et al., 2020).

SUSTAINABLE AGRONOMIC PRACTICES FOR CLIMATE CHANGE MITIGATION

1. Conservation Tillage

Conservation tillage refers to agriculture techniques that prevent soil disturbance and retain soil cover. This method is inclusive of no-till and reduce-till farming, both of which bring significant advantages to carbon sequestration and the soil health of the farmers through the disuse of tillage-ploughing.

- **No-Till Farming:** This method involves crop planting directly into an intact soil surface without prior plowing or tilling. With soil being undisturbed, zero tillage acts as the best practice for conservation that results in the protection of the soil's structure from eroding and water retention being reduced. An important benefit that such farming brings is that the soil organic carbon storage level increases as the intact soil traps carbon dioxide from the atmosphere and captures it in the soil structure (P. Smith et al., 2016). According to studies, switching to no-till systems can boost soil carbon stocks to 25% compared to traditional tillage methods. (Lal, 2015).
- **Reduced-Till Farming:** Reduced-till practices refer to soil practices with minor soil disturbance like shallow tilling or reducing the frequency of tillage. This method keeps more organic matter and soil moisture than conventional tillage. It also is good for maintaining soil structure and promoting helpful microbial activity. The scientific literature

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proposes that reduced-till methods allow for the growth of soil health, increased water penetration and carbon sequestration respectively (Olsen et al., 2014).

2. Organic Farming

Organic Agriculture is bigger than the use of composting and green manuring. It also indicates the possibility of errors in the process of agricultural nutrition and materials are exchanged. The critical principles of organic farming: using compost and green manuring provide the dual benefits of decreasing GHG emissions and diversifying soil life.

- **Composting:** Composting is defined as the breakdown of organic materials, such as plant residues and animal manures, in order to produce a nutrient-enriched soil amendment. The execution of compost in the soil, among other things, involves its influence over soil structure, water-holding capacity, and nutrient availability. Moreover, it facilitates the carbon cycle by recycling organic wastes and replacing expensive inorganic fertilizers, which produce a great amount of emissions (Gattinger et al., 2012). The incorporation of the compost has been observed as the constituent carbon that makes up soil and improves bacteria and fungi relationships (Lal, 2004).
- **Green Manuring:** This activity involves planting cover crops specifically for them to be mixed into the soil, to increase fertility and structure. Green manures, such as legumes, trap atmospheric nitrogen from the air to the soil, and thus limit the need for synthetic nitrogen fertilizers. Besides improving soil carbon content, using green manures stimulates carbon sequestration and supports microbial functional diversity as well (Drinkwater et al., 1998).

3. Integrated Soil Fertility Management (ISFM)

By integrating the use of organic and inorganic fertilizers in soil, ISFM is able to make better use of nutrients and improve soil health.

- **Use of combined organic and inorganic fertilizers:** One of the main principles of ISFM lies in the combination of organic parts (such as compost and green manures) and production of inorganic fertilizers thus solving the problems of soil degradation and fertility improvement. Thus, a comprehensive approach that promotes the inclusion of both organic farming and inorganic fertilization will ensure the supply of nutrients, improve the use efficiency of these nutrients, and at the same time, reduce the use of synthetic fertilizers significantly. When we use organic materials in ISFM, it facilitates soil organic carbon sequestration, and inorganic fertilizers, on the other hand, ensure the necessary nutrients for plants. The application of these fertilizers in combination has been found to increase crop yields, result in the formation of better soil structure, and reduce greenhouse gas emission from the soil (Zingore et al., 2007).

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- **Nutrient Management Practices:** One of the main principles of ISFM is the precise nutrient management which is working due to the application of fertilizers that are given corresponding to the balance between the findings of soil testing and the real needs of crops. It is a current movement to allow the production of food while saving the cost of nutritious inputs and the contamination of the environmental media. One of the key measures of nutrient management through ISFM systems is the conservation and enhancement of soil health. This will bring about a great side benefit in the form of climate change adaptation for the agriculture community (Vanlauwe et al., 2014). Top of Form

EFFECTS OF SUSTAINABLE AGRICULTURE ON THE SOIL AND YIELD IN AGRICULTURE

1. Soil Quality

Soil Physical Properties: Organcial practices in agriculture improve the physio-chemical characteristics of the soil, and these are core factors that determine the fitness of the soils. Some principles of conservation agriculture (CA) include minimum tillage such as no tillage practices. Literature review shows that no-till practices lead to additional aggregation of the soil material hence helps in soil aeration, water infiltration rates and checking of soil erosion (Sharma et al., 2012). More works have also indicated that, zero tillage practice has also enhanced the level of porosity and reduced the bulk density thus resulting in increased root growth and water holding capacity of the soil (Yogesh, Kumar, & Singh, 2020).

Soil Chemical Properties: Sustainable practices impact the soil chemical properties such as, organic carbon and the availability of nutrients. Activities like cover cropping and maintanance of organic amendments are also the main causes for increased SOC content. Hence, SOC is important in determiningility and fertility of soils, and plays a central role in enhancing nutrient availability as well as CEC. Higher SOC also aids in the process of carbon storage thus assisting in combating climate change (Bhattacharyya, Jha, & Kumar, 2023). Sharma et al. (2012) has brought out that conservation agriculture can improve available nutrient status through improved decomposition of organic matter and nutrient recycling.

Soil Biological Properties: The rate of biological health of the soils which in this case refers to microbial activity that is necessary for cycling of nutrients and thus fertility of the soils is also essential. Low-disturbance tillage and organic farming improve microbial abundance and functioning in the field. According to a study by Bhattacharyya et al. (2023), conservation agriculture practices enhance microbial biomass and activity to enhance the different aspects of nutrient cycling in the soil. The implication of diverse microbes in the depreciation of organic matter and the process of mineralization of nutrients that are significant in plant growth is evident.

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2. Crop Yields

Impact on Productivity: Sustainable agronomic practices may have positive and/or negative effects on the productivity of the crops. On the one hand, torings like no till age, cover crops and organic soil amendments have the ability to enhance soil health, consequently, implying the ability to increase crop yields over the long run (Yogesh, Kumar, & Singh, 2020). For instance, no-till farming practices have been demonstrated to raise yields since the farming technique enables better control of the soil structure and moisture that become valuable during the drought condition (Sharma et al., 2012).

Trade-offs Between Soil Conservation and Yield Outcomes: However, as much as sustainable practices are good for improving the health of the soils, there are some losses concerning the yields. For instance, it is quite known that when small holder farmers transition to conservation agriculture they record poor yields in the initial years because of the learning effects associated with new technologies, and the time required to get soil health improvement effects (Amisalu Milkias Misebo, 2018). However, integrating the organic inputs enhance the physical characteristics of the soil though the availability of the nutrients might decrease in the short run compared to the synthetic fertilizers.

Long-term vs. Short-term Yields: In the long run, therefore sustainable practices normally have positive impact on productivity due to the raised organic matter in the soil. For instance, Bhattacharyya et al. (2023) indicated that even though there is a decrease in yields with the initial use of conservation agriculture, improvement and stability in the future with increase in SOM and nutrient availability results to high crop yields.

Conclusion: The changes that can be observed in the long term as the result of utilizing the sustainable agronomic practices are hard to generalize as the effect on the soil health and productivity depends on many factors. All these practices enhance the physical, chemical, and biological properties of soil in ways that enhance long term health and fertility of the soil. It is understood that in the short run some exchanges in the yields of crops will be necessary and the advantages with regard to improved ground quality and environmentally friendly impact prevail over productivity advantages in the long-term term. Further research and improvements on the methods which will help to improve on the status of the soils besides enhancing the productivity of the crops are very crucial.

3. Challenges and Barriers

Economic constraints

This we see is due to a number of factors most of which are generally financial factors that hinder the implementation of sustainable agronomic practices. When it comes to sustainable farming, cost

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is one factor that has discouraged many farmers by the time they started which can be very expensive. Such costs may include expenses into acquiring certain machinery and seeds for practices like CA or AF or costs of putting in place structures for implementing certain soil conservation measures. For instance, adopting CA principles like zero tillage and mulch have called for use of specific seeds and tool, which are often costly hence could be out of reach for the small holder farmers (Sharma, Shah, & Roy, 2012).

Also, costs, which are likely to occur in the course of adopting sustainable practices, may be discouraging. Farmers might experience some level of risk concerning the productivity enhancement initiatives where they include but not limited to the doubt if the new practices would increase yield or not, the time gap between the adoption of the new practices and the time the yields will increase, and whether the market prices of their produce would cover the cost of practicing the new techniques. Financial risks, which the authors list below, can also pose a challenge to farmers who would like to engage in sustainable practices because the benefits of such an approach are not always clear or assured by market conditions Yogesh, Kumar, & Singh (2020). These economic limitations can only be solved by a well-aimed financial intervention in the form of subsidies and cheap credits, as well as insurance tools aimed at minimizing the danger connected with the innovation of new methods of crop production.

Knowledge gaps

Knowledge gaps represent another critical barrier to the widespread adoption of sustainable agronomic practices. Farmers themselves are often unaware of the specifics or professionalism concerning the advantages and the ways of applying the sustainable farming techniques. As noted by Bhattacharyya et al. (2023), knowledge dissemination of climate change practices, including soil carbon confinement and reduction of greenhouse gas emission through conservation agriculture, should be optimized for boosting conservation practices' adoption (Bhattacharyya, Jha, & Kumar, 2023).

Information chasms are equally important to note since they reveal the areas in which the extension services are important where there are knowledge gaps that need to be filled. Increase the availability of ready actionable information, training, and materials needed for adoptation of sustainable practices by farmers. However, in many regions, extension services are poorly funded and the specialized staff is scarce resulting in low coverage of services. According to Misebo (2018), the enhancement of the services of extension and fourth the investment in the education of agriculture is important as these make farmers be acquainted with sustainable practices and the yield of the practices. (Misebo, 2018).

Policy and institutional support

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Policies and institutions of the government have a central role in encouraging or discouraging use of sustainable agronomic practices. They are the governmental authorities, and they directly affect farmers' decisions, offering incentives, formulating beneficial regulations, and financing various research undertakings. For example, supportive policies may be in the form of grants for purchase of sustainable inputs, tax exemptions on environmentally friendly practices and or research grants/ funding in sustainable agriculture (Sharma et al., 2012).

On the other hand, lack of or improper policies can also be a hindrance to adoption. Inadequate policies may demotivate the adoption while those that are designed inappropriately may [.]; Poor policies may discourage the adoption while those that are formulated unsuitably may [.] For instance, lack of rules that state and explain what is allowed and what is not, inadequate implementation of environmental standards or policies, and policy inconsistencies that might include measures that do not go well with sustainable practices can pose challenges to farmers intending to go green. Yogesh et al. (2020) opine that it is necessary to have proper policies for coordination of different stakeholders involved in encouraging the sustainable practices in the agricultural sector such as governmental bodies, research establishments, and farmers. It also involves the readiness of agricultural organizations and cooperative to help in the provision of inputs, providing technical support and lobbying for the change of policies. If there is no support from the institutions then sustainability programs do not work and there is a demotivation to go for sustainable practices among the farmers. Therefore, encouraging the policymakers, institutions as well as farming population to form good synergies normally guarantees the best environment for sustainable agriculture (Bhattacharyya et al., 2023).

Case Studies and Success Stories in Sustainable Agronomy for Soil Conservation and Climate Change Mitigation in India

REGIONAL EXAMPLES

1. Punjab: Conservation Agriculture and Zero Tillage

In Punjab, the adoption of Conservation Agriculture (CA) practices, particularly zero tillage, has been a notable success. This approach, characterized by minimal soil disturbance, has led to significant improvements in soil health and crop yields. A study by Sharma, Shah, and Roy (2012) highlights that zero tillage in Punjab has reduced soil erosion, enhanced moisture retention, and improved nutrient availability. The introduction of zero tillage, combined with the use of cover crops and crop rotations, has resulted in increased wheat and rice yields while reducing greenhouse gas emissions from soil management practices (Sharma, A., Shah, K., & Roy, S., 2012).

2. Tamil Nadu: Agroforestry and Soil Health Improvement

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In Tamil Nadu, agroforestry practices have demonstrated successful integration of trees with crop and livestock systems. The research by Misebo (2018) indicates that agroforestry has enhanced soil fertility, reduced erosion, and improved water management. Farmers in this region have adopted tree-crop combinations, which provide additional income and ecological benefits. For example, integrating cashew and coconut trees with traditional crops has not only diversified farm income but also contributed to better soil structure and moisture conservation (Misebo, A. M., 2018).

3. Uttar Pradesh: Integrated Crop Management

In Uttar Pradesh, integrated crop management (ICM) practices have been successfully implemented to manage soil health and productivity. Yogesh et al. (2020) report that ICM, which includes practices such as integrated pest management, balanced fertilization, and crop rotation, has improved soil fertility and reduced the need for chemical inputs. This approach has also enhanced resilience to climate change by promoting sustainable farming practices that mitigate soil degradation and increase crop yields (Yogesh, K., Kumar, A., & Singh, R., 2020).

COMMUNITY INVOLVEMENT

1. Farmer Organizations in Andhra Pradesh

In Andhra Pradesh, especially farmers have come in different organizations and associations to extend their support towards the sustainable farming practices. Local farmer groups have been effectively involved in initiatives of raising consciousness of conservation agriculture, organic farming, and water management. As stated by Bhattacharyya et al. (2023) these organisations have enabled the training institutions, availed learning materials, and developing the capacity to share information and knowledge to farmers. They have enhanced the practices like vermicomposting and rainwater harvesting which has proved beneficial in enhancing the soil health and water management practices in the area (Bhattacharyya, R., Jha, P., & Kumar, R., 2023).

2. Soil conservation and its agency in Gujarat

Efforts to mobilise the Gujarat communities to participate in the farming practices have been realised through the citizens' own soil conservation measures. The carrying out of check dams, bunding, and contour ploughing has been facilitated by the people's participation and the native leadership. Most of the current carried out soil conservation projects have incorporated the local community in the planning as well as implementation process thus improving the rate of maintenance and efficiency in the practices. Some of the observations from the latest research conducted focuses on the fact that increased community participation in such activities has increased fertility in regard to soil erosion, He admitted that sustainable agriculture required an active participation of the locals (Misebo, A. M. , 2018).

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3. Women Farmers in Karnataka

Women farmers are actively involved in practicing sustainable agriculture and they are the driver of change in Karnataka. Through their engagement in such activities as the organic farming and agroecology, the capacity of women has been boosted economically and farm productivity has been boosted as well. Of the practices targeted at training women the composting and soil management practices a number of success stories have been observed. These programs have proved that the Accent of the woman can lead the higher changes in agriculture improvement and climate change resilience (Yogesh, K., Kumar, A., & Singh, R., 2020).

RECOMMENDATIONS FOR FUTURE RESEARCH AND POLICY

RESEARCH NEEDS:

1. Long-Term Impacts of Specific Practices: For future research recommendation, more efforts should be directed towards a long-term analysis of the effects of the agronomic practices on the soil health, crop yield and climate change. For instance, even though CA measures like zero tillage as well as mulching have some positive short run impacts on the conservation of the soil and productivity as presented by Sharma et al., (2012) and Yogesh et al., (2020), the long run effects of these measures on the structure of the soil, the nutrient content and the ecology are still unknown. Studies that follow these beliefs will enhance understanding of the variables' sustainability and efciency within the context of various agro-ecological regions over time (Bhattacharyya et al., 2023).

2. Scalability of Sustainable Practices: Another important research domain of great concern is the factors that determine the application of sustainable agronomic practices. Assessing how the application of these practices can be taken to other places, and changed to suit different geographical areas and farming types is therefore important. Studies should endeavor to find out options that are economically profitable, technically suitable, and socially acceptable for practice of practices such as, agroforestry, intercropping, and cover cropping in different agro-climatic regions (Misebo, 2018). This includes evaluating factors that may hinder their adoption and finding ways through which most of these practices can be incorporated into commercial farming.

3. Interactions Between Agronomic Practices and Climate Change: This research will help improve the understanding of how climate change factors like temperature variability, changes in precipitation and CO2 level affects various procedures of agronomics and improve climatic change adaptation and climate change mitigation. Further, research should aim to explore how these practices can be further enhanced for the purpose of climate change resilience, and improving soils' ability to mitigate climate change by reducing emissions and sequestering carbon (Bhattacharyya et al., 2023).

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4. Socioeconomic Impacts: More studies should also be conducted to explore the social/economic operations of sustainable agronomic systems on the income of farming enterprises, employment status, and rural communities. It is vital to know how these practices affect the economic development of the farming societies and contribute to social justice and aspire to devise the right measures that will be more appropriate and efficient (Yogesh et al., 2020).

POLICY RECOMMENDATIONS:

1. Financial Incentives: Therefore, the policy measures with most acceptable tools should comprise of financial tools like subsidies, grants and preferably low interest loans to support the use of sustainable agronomic practices. Besides, financial assistance may assist in financing initial investments in such measures as, for instance, conservation tillage, organic production or agroforestry. For instance, governments can pay for costs relating to the procurement of equipment, seeds or soil inputs that are friendly to the environment (Sharma et al., 2012). Also, the possibility of offering tax exemptions to the farmers that embrace sustainable farming practices may help enhance adoption.

2. Training and Capacity Building: Education, through institutes and other service providers, is another important factor needed to introduce sustainable agronomic practices to the farmers. Such training must diplomatically aim at creating awareness to farmers about the advantages and the proper ways of undergoing practices such as cover cropping, strip cropping, and integrated pest management. Other measures that need to be adopted in capacitating the stakeholders include organizing more of the skills-boosting capacity building activities such as workshops, field demonstrations, and farmer-to-farmer knowledge sharing in order to strengthen practical skills and knowledge (Misebo, 2018).

3. Research and Development Support: Funding annual research projects must be provided by policy measures towards stimulating, promoting and encouraging R & D in sustainable agriculture. Public sector and donating foundations should focus on the topicality, novelty, and applicability of the research to advance sustainable practices with regard to evaluating their efficiency in various settings (Bhattacharyya et al., 2023).

4. Infrastructure Development: It has been said that establishing the framework that would enable the practical application of sustainable agronomy is indispensable. This entails funding for water harvesting structures, soil sample testing equipment and market for organically produced food and other products. Development of better and upgraded infrastructure can go a long way in eliminating some of these hurdles affecting farmers and on the same note, enhance the effectiveness of the sustainable practices among farmers (Yogesh et al., 2020).

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5. Policy Integration and Coordination: Policies related to agriculture, environment, and rural development should be integrated and coordinated to promote sustainable agronomic practices. Ensuring that agricultural policies align with environmental goals and support sustainable land management can create a more cohesive framework for practice adoption (Sharma et al., 2012). Coordination between different government agencies, NGOs, and private sector stakeholders can enhance the effectiveness of policy interventions and support the scaling up of sustainable practices.

By addressing these research needs and implementing these policy recommendations, we can advance the adoption of sustainable agronomic practices, enhance their benefits, and contribute to soil conservation and climate change mitigation in India.

SUMMARY

Therefore, drawing conclusions, the review highlights the large advantages of following the sustainable agronomic production techniques for protecting the soil and combating climate changes in India. Conservation Agriculture (CA) THAT involves minimum soil disturbance, maintaining ground cover, and practicing of crop rotation among others increases the soil health, reduces the rate of soil degradation and increases productivity (Sharma et al., 2012). These practices improve resource utilisation efficiency and play an important role in managing climate change issues through lowering greenhouse gas emission and benefiting from the soil C pool (Bhattacharyya et al., 2023).

Practices like zero tillage, mulching, crop rotation have been quite useful in controlling soil erosion, conserving soil moisture and fertility which in turn increases the farm income and its sustainability (Yogesh et al., 2020). Also, the agronomic practices such as strip cropping, inter cropping, and agro forestry have proven to exert positive impacts including, protection of soil from erode, conservation of water and improvement of soil fertility (Misebo, 2018). Such practices also have positive effects towards the physical condition of the land and contain potentials for handling the effects the climate change has on the environment.

FUTURE OUTLOOK

Based on these best practices of sustainable agronomy the future holds a lot of potential for expanding recommendations for the diversified agronomic zones of India. The outreach of such practices can further be scaled up and can help to have positive impacts such as better soil health, better yield, and better adaptability to climate change. However, this scaling-up endeavour is going to need a coordinated strategy that comprises additional research, consistent development of effective policies and the application of further, tangible implementation initiatives.

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Subsequent studies should further improve and scale up the identified practices according to different agro-ecological zones, determine extended effects and possible hurdles associated with technologies and socioeconomic setting. In addition, policy support which implies the provision of favorable environment that will encourage the adoption of sustainable practices by as many establishments as possible cannot be overemphasized. This entails availing to farmers modern implements, teaching aids, and monetary incentives to facilitate the change of the farming techniques.

Moreover, the encouragement of cooperation with other research organizations, governmental bodies, and agriculture producers will be critical to improving sustainable agronomy. Thus, a proper mixture of research and development along with the actual experience and policies can help India achieve further enhancements in the fields of soil conservation and climate change, which in turn would help in strengthening the agriculture sector in the future.

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