Review Article

Integrated Approach to Agronomic Management: Balancing Productivity and Environmental Sustainability

Abstract

All global development is based on the agricultural practice. If not managed responsibly, increasing its productivity and production might impact the land's capacity in the future. Preserving potential land use might be achieved through sustainable agriculture. Enhancing and balancing productivity with environmental sustainability may be accomplished by concentrating on locally accessible organic resources, INM, IFS, etc. and proper soil health management. Due to their high input usage efficiencies, decreased use of synthetic fertilizers and pesticides, and enhanced soil resilience and quality in a changing climate, they might increase agricultural output and ecosystem sustainability. This review briefly overviews sustainable agriculture, its components, and the potential to achieve overall sustainability by integrating innovative agronomic approaches and practices to meet the increasing demands for food while preserving the environment.

Keywords:*Agronomic practices, innovation, productivity and environmental sustainability*

1. Introduction

Agriculture is the world's largest industry and a significant land use, providing 40% of the world's food and occupying the most accessible land [1]. The agriculture industry plays a significant role in the global economy's growth. Due to the rising population and associated food security issues, developing nations still confront the most severe challenges. Increasing agricultural productivity using external inputs like pesticides and mineral fertilizers was the only way to increase food production in the 20th century [2,3]. Modern agricultural methods built upon the green revolution have resulted in a notable rise in grain production at the price of diminishing natural resources. Because of the externalization of agriculture, soil fertility and environmental resilience deteriorated considerably [4]. It demands alternative approaches that educate farmers on applying their customary knowledge to yield more excellent grains while

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using less external inputs. Sustainable agriculture is the term for this approach, which is crucial right now.

Sustainable agriculture refers to farming practices that maximize the use of non-renewable resources, help the environment, and expand natural resources [5] without compromising the ability of current or future generations to meet their needs. Sustainable agriculture encompasses agricultural practices that are fair to the environment and enable the production of animals or crops without endangering human or natural systems. A viable way to allow agricultural systems to feed an expanding population while adjusting to changing environmental circumstances is through sustainable agriculture [6]. Sustainable agriculture helps the food production system become more resilient and stable by recognizing and utilizing ecological services. To ensure a safe and prosperous future for all the current tasks, keep creating and putting these sustainable methods into reality worldwide [7].

Integrated use of a range of soil, fertilizer, and pest management strategies, such as crop residue, manure, mixed cropping, and crop rotation methods, have been promoted in sustainable agriculture [8, 9]. These methods improved soil quality, nutrient pools, climatic resilience, and ecosystem restoration while reducing soil degradation, which raised farmers' socioeconomic standing. The core tenet of sustainable agriculture is that productivity must increase while resource use must decrease. To accomplish the core objectives of sustainable agriculture, various innovative alternative techniques have been put forth, including precision agriculture, water-saving agronomic techniques, IFS, INM, biofertilizers, conservation agriculture, and organic farming for soil management. With an emphasis on sustainable crop production, this review thoroughly investigates the development of agronomic methods. The goal is to examine how these methods balance productivity while enhancing social welfare, economic viability, and environmental sustainability [10].

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2. Advances in Agricultural Practices

The development of agronomic techniques from their historical foundations to contemporary advances illustrates how agriculture is a dynamic and adaptable industry. Obtaining an appreciation of this history is essential to understanding farming techniques' current and future directions. Agronomy was initially entwined with the cycles of the natural world. Most of these methods relied on rain feeding and emphasized regionally appropriate crop types [11].

Traditional practices ranged considerably, from terraced cultivation in hilly areas to the slash-and-burn approach in tropical woods [12]. These methods frequently used organic waste as fertilizer and were sustainable and well-suited to the local environment; however, they cannot support a more significant population because of decreased productivity and the possibility of soil depletion [13].

These conventional practices saw a dramatic shift with the advent of modern agriculture. Beginning in the 1960s, the Green Revolution brought herbicides, synthetic fertilizers, and crop types with higher yields, significantly changing the agricultural landscape [14]. An essential component of this revolution was mechanization, which increased production and efficiency by substituting tractors and combining harvesters for most of the physical labour [15]. Governments worldwide started modifying their agricultural policies to accommodate this new technology, frequently offering subsidies for fertilizers and better seeds and encouraging monoculture methods motivated by consumer demand [16]. Agricultural techniques were evaluated when the effects of intensive farming practices on the environment and society became evident. This has led to modern ideas and trends that balance sustainability and productivity.

The desire for more effective and ecologically friendly farming methods led to precision agriculture. Precision agriculture takes advantage of developments in big data analytics, IoT devices, and GPS technology to help farmers maximize resources like pesticides, fertilizers, and water [17]. This strategy reduces farming's adverse environmental effects while increasing yield [18]. Another significant development is organic farming, which substitutes natural solutions for artificial ones. Organic farming focuses on crop rotation, biodiversity preservation, natural fertilizers and pest management to build a more sustainable agricultural environment [19]. Biological, cultural, and chemical methods are all included in integrated pest management (IPM), an all-encompassing approach to pest management. IPM tackles health and environmental issues by minimizing the usage of hazardous chemicals. It successfully preserves agricultural yields while lowering the need for pesticides [20]. With the globe still facing population increase, climate change, and environmental degradation, agronomic techniques, such as INM, IFS, etc., are more critical than ever for evolution. Agriculture's adaptable character is shown by the shift from conventional to contemporary to creative, sustainable techniques, reflecting humanity's continuous effort to balance environmental stewardship and productivity.

3. Novel Agronomic Approaches for Sustainable Agriculture

Adopting cutting-edge strategies that maximize environmental effects while maintaining production is essential to advancing sustainable agriculture [21]. These tactics are created with particular values and objectives in mind, frequently addressing agriculture's social, economic, and environmental facets. While some strategies, like carbon farming, came into being with a strong focus on environmental policy, others, like agroecology and sustainable intensification, have evolved [22]. These strategies' flexibility enables them to accommodate a range of production circumstances and methods, frequently with well-established industry recognition and expert assistance, such as organic farming [23,24].

Climate-Smart Agriculture (CSA): An essential strategy for tackling the problems caused by climate change and how it affects agriculture is called "climate-smart agriculture," or CSA. It strives to enhance agricultural methods to increase productivity, adjust to a changing environment, and reduce greenhouse gas emissions. Due to the FAO's estimate that worldwide agricultural and livestock output must increase by 60% by 2050 compared to 2006 levels to fulfil demand, the need for CSA has grown as climate change threatens food and nutrition security. To minimize environmental deterioration, CSA provides a thorough framework for accomplishing these objectives. CSA aims to increase productivity while lowering greenhouse gas emissions by improving soil and plant carbon sequestration [25].

A fundamental component of CSA is mitigation, which aims to cut or completely eradicate greenhouse gas emissions from agriculture. To do this, it promotes methods that allow plants and soils to function as carbon sinks, lowering the total carbon footprint of agricultural activity. By increasing agricultural yields, livestock output, and fisheries while reducing their adverse environmental effects, CSA also seeks to increase food and nutritional security [26]. The strategy recognizes that trade-offs may arise but can be controlled through efficient institutions, laws, and funding sources. It aims to strike a balance between productivity, adaptation, and mitigation objectives. CSA aims to develop a more sustainable and resilient agriculture system that can both protect the environment and feed the world's expanding population.

Organic Farming: Environmental preservation, animal care, food safety and quality, resource sustainability, and social justice are all prioritized in organic farming [27]. It uses market mechanisms to help achieve these goals and pay for internalized environmental externalities. The goal of organic farming is to establish humane, sustainable, and integrated production systems that manage biological and ecological processes, rely on renewable resources derived from farms, and ensure acceptable levels of crop, livestock, and human nutrition while offering a just reward for labour and other resources [22]. Numerous agricultural and ecological advantages come from organic farming. It encourages sustainable farming methods, biodiversity preservation, pollution reduction, and soil health. It uses less synthetic pesticides and emphasizes biological pest management, natural fertilizers, and other environmentally beneficial techniques.

Additionally, organic farming is known to provide high-quality, chemical-free food [23], so people are concerned about their health like it. Respect for the environment and animals, sustainable cropping practices, the use of non-chemical pesticides and fertilizers, the production of high-quality food, and the avoidance of genetically modified (GM) crops are some of the main characteristics of organic agriculture [28]. Food security is the goal of organic farming, which uses minimal external inputs and ecologically responsible methods [29]. It has become more widely accepted in society, allowing farmers to fulfil consumer demand for organic products while encouraging environmental stewardship.

Biodynamic Agriculture: An alternative to organic farming, biodynamic agriculture blends organic methods with metaphysical ideas derived from Rudolf Steiner's teachings. It is among the first organic agriculture movements, founded in 1924. Creating a harmonious interaction between the earth, plants, and animals is the primary goal of biodynamic techniques, which frequently consider cosmic rhythms like solar and lunar cycles to direct planting and harvesting. Organic and biodynamic farming both refrain from using synthetic chemicals and genetically modified organisms. The goals of biodynamic methods are to regenerate the soil, give life back to plants and animals, and eventually heal the world. Both organic and biodynamic farming exclude synthetic inputs, while biodynamic farming emphasizes sustainability and adaptation to different climates, promoting a broader ecological approach. Encouraging farmers to match their operations with natural cycles strengthens agricultural resilience and fosters a closer relationship with the environment.

Integrated Farming Systems (IFS): An agriculture method known as integrated farming systems (IFS) blends several forms of production, such as fish and livestock or cattle and grains. This integration is akin to natural ecosystems, in which disparate components coexist and "waste" from one becomes an input for another. Farmers may lower expenses, cut waste, and boost income and production using IFS. The idea is founded on a circular economic paradigm, in which all system elements support one another, and nothing is wasted. Combining crops with other aquatic plants, animals, fish, birds, and other wildlife is common in integrated agricultural systems [30]. This strategy can increase biodiversity by lowering competition for resources like water and nutrients through crop rotation, intercropping, and mixed cropping. Increased production and more effective agricultural management may result from this variety. Beyond efficiency, IFS can improve ecological sustainability by encouraging natural cycles in the agricultural system and lowering the demand for artificial inputs [31]. Farmers may increase yields and contribute to a more sustainable agricultural model by establishing linked subsystems. This all-encompassing farming method is consistent with sustainability, offering a foundation for healthy and ecologically responsible farming operations.

Integrated Nutrient Management (INM): INM refers to the maintenance of soil fertility and plant nutrient supply at an optimum level for sustaining the desired productivity through optimization of the benefits from all possible sources of organic, inorganic and biological components in an integrated manner. One of the most essential agronomic management practices is integrated nutrient management (INM), which focuses on fertilizer nutrient supply to meet crop requirements while minimizing input costs [32]. The INM also employs the use ofspecific microorganisms along with a minimum effective dose of adequate and balanced amounts of organic and inorganic fertilizers. Blending chemical fertilizers with organic manure is turning out to be a perfect strategy for maintaining production, enhancing soil health, and guaranteeing environmental advantages in addition to larger yield output. For the proliferation of soil microorganisms, the organic component of integrated nutrient management provides accessible nitrogen, organic carbon, and energy. A significant goal of integrated nutrient management (INM) is achieving environmental benefits. This is accomplished by fusing the beneficial qualities of both organic and inorganic sources to create a blend that can be used to reduce the use of chemical fertilizers sparingly, maintain a balance between fertilizer inputs and crop nutrient requirements, improve soil fertility, maximize yield, maximize profitability, and minimize pollution [33].

Site-specific crop management (SSCM)/Precision Farming: Site-specific crop management (SSCM), sometimes referred to as satellite farming or precision agriculture (PA), is a farming technique that uses technology to enable farmers to monitor, assess, and control crop variability within and between fields [34]. This technique aims to create a decision support system (DSS) that will optimize resource conservation and input utilization for whole-farm management. To increase crop yields and facilitate wise management decisions, precision farming uses cutting-edge technology, data analysis, and sophisticated sensors [34]. An essential part of precision farming is site-specific management (SSM), which emphasizes "doing the right thing at the right time and in the right place [36]. This method adjusts agronomic procedures to field circumstances using yield monitors, remote sensing, and variable rate applications (VRA) [37]. With the development of GPS and GNSS technology, farmers can now produce intricate maps that illustrate the regional variability of important agricultural factors, facilitating the accurate application of inputs such as pesticides, fertilizer, and water [38]. Improved crop quality, decreased environmental impact, and more efficient use of resources are just a few advantages of precision farming. Maximizing essential inputs encourages sustainability by increasing yields, lowering the need for fertilizer and pesticides, conserving fuel, and improving water management [39].

Agroforestry: The deliberate blending of land-use systems based on forestry and agriculture, or agroforestry, has several advantages for long-term sustainability. This strategy may restore damaged areas, protect delicate ecosystems, and diversify agricultural production methods. Agroforestry techniques support environmental quality and the preservation of ecosystem variety when paired with ecologically focused land management. Agroforestry benefits the environment and economy alike, particularly when mitigating the drawbacks of contemporary agriculture and advancing sustainable natural resources and agricultural systems. [13]. It establishes integrated systems that serve economic and environmental objectives, thus bridging the gap between forestry and agriculture. Agroforestry may defend against wind and water erosion, increase yearly plant yields, and assist agricultural systems in adapting to and mitigating the consequences of climate change [14]. Agroforestry also uses strips of land with trees and bushes to provide habitats and refuges for various plants and animals. Agroforestry is a sustainable method of using land that promotes better biodiversity, resource management, and adaptation to environmental issues. Because it encourages environmental care and long-term productivity, it is consistent with the tenets of sustainable agriculture [25].

4. Advancement in Modern Agronomic Practices

With an emphasis on productivity, sustainability, and adaptability to environmental changes, agronomic techniques have developed to meet the demands of contemporary agriculture (Table 1).

Table 1. Advancement in modern agronomic practices

Particulars area	Description	Examples
Sustainable Practices	Approaches that promote environmental stewardship.	➢ Organic farming ➢ Conservation tillage ➢ Agroforestry
Climate Resilience	Strategies to adapt and mitigate the impacts of climate change.	➢ Drought-tolerant varieties ➢ Crop diversification ➢ Weather forecasting models
Soil Management	Techniques to maintain or improve soil health and fertility.	➢ Crop rotation ➢ Cover crops ➢ Organic amendments
Precision Agriculture	Use of technology to optimize field-level management.	➢ GPS-guided equipment ➢ Remote sensing ➢ Data analytics for decision making
Irrigation Technology	Improvement in methods to supply water to crops.	➢ Drip irrigation ➢ Sprinkler systems ➢ Computerized irrigation control
Crop Genetics	Development of crop varieties with enhanced traits.	➢ Genetically Modified Organisms (GMOs ➢ Hybrid crops ➢ Disease-resistant strains
Pest and Disease Control	Methods to protect crops from pests and diseases.	➢ Integrated Pest Management (IPM) ➢ Biological control agents ➢ Pesticides and herbicides

Farm Machinery and Automation	Advances in machinery and Automation for farming efficiency.	➢ Autonomous tractors ➢ Drones for monitoring ➢ Robotic harvesters

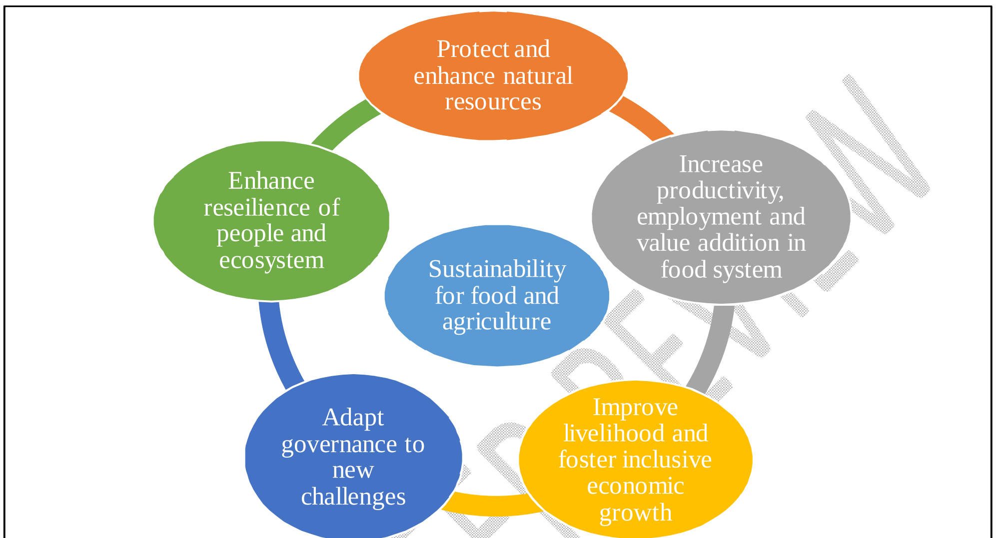
With an emphasis on resilience, productivity, and sustainability in an ever-changing agricultural environment, these significant areas of improvement reflect the continuous evolution of agronomic methods. Sustainable agriculture is supported by methods that improve soil health, such as crop rotation, cover crops, and organic amendments. Crop irrigation efficiency has increased thanks to innovative techniques for delivering water; integrated pest management (IPM), which combines biological, chemical, and cultural controls to reduce the need for pesticides, is one such technique for safeguarding crops against pests and diseases [40]. Farmers can now apply inputs more precisely thanks to this technology, which lowers waste and boosts output. Environmental stewardship-focused strategies are becoming more popular. Sustainable farming strategies that boost agricultural production and ecological health include agroforestry, conservation tillage, and organic farming [41].

5. Balancing Productivity with Environmental Sustainability

Agricultural productivity aims to preserve the natural resource foundation that underpins future food production while also helping to feed the world's growing population. The importance of agriculture is growing, and it will continue to do so in light of the industry's projected continued expansion, the most recent developments in agricultural technology, and the shift to sustainable agricultural practices [42,43]. As a result, an integrated approach to agricultural systems is not only appropriate but also required.

One of agriculture's most significant issues is balancing sustainability and production. The two objectives complement one another and are not mutually incompatible. A range of instruments and strategies known as Sustainable Food and Agriculture (SFA) are intended to guarantee the social, environmental, and financial sustainability of food production and consumption with 5 fundamental principles (Fig. 1). In addition to reducing severe hunger and promoting food security, SFA also seeks to safeguard the environment, guarantee healthy lifestyles, and advance prosperity for all people, regardless of age. Significant disparities exist in the philosophies, methods, and degrees of execution among the many nations that have previously made steps and endeavours to reform their food systems.

Fig. 1: Sustainability for food and agriculture fundamental principles



(Source: FAO [44])

The primary challenge facing global agriculture is meeting the rising demand of an estimated 9 billion people by the year 2050 when there will be approximately 7 billion people on Earth. The expansion of productive agricultural land is limited, and climate change may impede efforts to balance productivity and sustainability. The demand for food and other agricultural products is expected to increase by 50% between 2012 and 2050. To attain balance, additional development alternatives include (i) advocating for conservation agriculture and good agricultural practices, (ii) encouraging mechanization through robotics and ICT, (iii) growing value chains and agro-processing, (iv) enhancing food safety and quality compliance through institutional development and international collaboration for building capacity to handle Sanitary and Phytosanitary measures (SPS) standard and certification compliance; and (v) knowledge creation and technological advancement [45]. The development of climate-smart agriculture technologies must prioritize output and resource efficiency increases.

6. Way forward

A holistic strategy that incorporates cutting-edge agronomic techniques, environmental physiology, and adequate plant nutrition is essential for the future of sustainability. Climate change and population expansion are increasing the need for food, and sustainable agriculture has to adapt to meet these demands while reducing its adverse effects on the environment. The application of technology to increase productivity and accuracy will be a crucial component of future agronomic techniques. Another crucial subject is sustainable soil management, which focuses on methods for restoring and preserving soil health. Organic amendments, decreased tillage, and cover crops—practices that enhance soil structure and biodiversity—are anticipated to increase. These methods improve soil fertility, lessen erosion, and sequester carbon. Agriculture that is robust to climate change is essential.

Developing cultivars more resilient to harsh weather, such as heat- and drought-tolerant ones, will be a future strategy. Farmers may avoid climate-related risks and ensure steady crop production despite changing climates by using diverse cropping systems and modern weather forecasting models. Studying plant reactions to stresses or environmental physiology will remain crucial to sustainable agriculture. Sustainable agriculture relies heavily on plant nutrition, and new strategies will try to maximize nutrient utilization while reducing environmental effects. Precision agriculture will make More effective fertilizer applications possible, and environmentally friendly substitutes like plant growth-promoting microorganisms (PGPMs) and biofertilizers will become more popular, improving soil health and lowering the demand for synthetic fertilizers.

In balancing productivity with sustainable agriculture, incorporating ecosystem-based practices like permaculture and agroforestry will be crucial [31]. These methods improve biodiversity, support a more balanced agroecosystem, and offer ecosystem services. Cooperation between scientists, farmers, legislators, and industry stakeholders is crucial to promote innovation in sustainable agriculture. Encouraging sustainable practices through supportive policies and regulations is essential to building a resilient and productive agriculture sector. To summarise, a comprehensive strategy that integrates cutting-edge technology, climate resilience, and environmentally friendly practices is necessary for the future of sustainable agriculture. By embracing these strategies, sustainable agriculture can meet global food demands while safeguarding the environment for future generations.

7. Conclusion

Achieving sustainable agriculture and production balance without endangering the environment for coming generations is possible and a must. Understanding and properly managing the components of sustainable development is possible. To meet the increasing needs of a proliferating world population, advanced agronomic practices, environmental physiology, and adequate plant nutrition must be integrated. The primary objective is to preserve long-term ecological health and reduce environmental effects while producing adequate food. Organic additions and proper soil management strategies are becoming more popular because they enhance ecosystem services and preserve soil health. Another crucial area of research is climate resilience, which includes creating crops resistant to drought and utilizing weather forecasting models to adjust to a changing environment. Food security issues may be met while protecting the environment for future generations by combining sophisticated agronomic methods, environmental physiology, and adequate plant nutrition. Maintaining an agricultural industry that is resilient and productive will need a continuous commitment to innovation and sustainability.

References

1. Singh R, Singh H, Raghubanshi AS. Challenges and opportunities for agricultural sustainability in changing climate scenarios: A perspective on Indian agriculture. Tropical Ecology. 2019;60:167-185.
2. Urgesa AA, Abegaz A, Bahir AL, Antille DL. Population growth and other factors affecting land-use and land-cover changes in north-eastern Wollega, Ethiopia. Tropical Agriculture. 2016;93(4):298-311.
3. Mekuria W. The link between agricultural production and population dynamics in Ethiopia: A review. Advances in Plants & Agriculture Research. 2018;8(2):348-353.
4. Laishram B, Devi OR and Ngairangbam H. Insight into Microbes for Climate Smart Agriculture. Vigyan Varta. 2023; 4(4):53-56.
5. USDA. Sustainable Agriculture | National Agricultural Library. (n.d.). https://www.nal.usda.gov/farms-and-agricultural-production-systems/sustainable-agriculture#:~:text=Sustainable%20agriculture%20is%20farming%20in,best%20use%20of%20nonrenewable%20resources.
6. Rockström, Johan; Williams, John; Daily, Gretchen; Noble, Andrew; Matthews, Nathanial; Gordon, Line; Wetterstrand, Hanna; DeClerck, Fabrice; Shah, Mihir (2016-05-13). "Sustainable intensification of agriculture for human prosperity and global sustainability". Ambio. 46 (1): 4–17. doi:10.1007/s13280-016-0793-6.

7. Shah F, Wu W. Soil and crop management strategies to ensure higher crop productivity within sustainable environments. Sustainability. 2019;11(5): 1485.
8. Mutyasira V, Hoag D, Pendell D, Yildiz F. The adoption of sustainable agricultural practices by smallholder farmers in Ethiopian highlands: An integrative approach. Cogent Food & Agriculture. 2018;4(1):1552439.
9. Brock C, Oltmanns M, Matthes C, Schmehe B, Schaaf H, Burghardt D, et al. Compost as an option for sustainable crop production at low stocking rates in organic farming. Agronomy. 2021;11(6):1078.
10. Devi OR, Ojha N, Laishram B and Devi OB. Opportunities and Challenges of Soil Fertility Management in Organic Agriculture. Vigyan Varta. 2023; 4(8): 228-232.
11. Monyo ES, Varshney RK. Seven seasons of learning and engaging smallholder farmers in the drought-prone areas of sub- Saharan Africa and South Asia through Tropical Legumes, 2007- 2014. international crops research institute for the Semi-Arid tropics; 2016.
12. Misbahuzzaman K. Traditional farming in the mountainous region of Bangladesh and its modifications. J Mt Sci. 2016; 13(8):1489-502.
13. Aguilera E, Díaz-Gaona C, García-Laureano R, Reyes-Palomo C, Guzmán GI, Ortolani L et al. Agroecology for adaptation to climate change and resource depletion in the Mediterranean region. A review. Agric Syst. 2020; 181:102809.
14. Hazell PB. An assessment of the impact of agricultural research in South Asia since the green revolution. Handbook of agricultural economics. 2010;4:3469-530.
15. Hasan K, Tanaka TS, Alam M, Ali R, Kumer Saha CK. Impact of modern rice harvesting practices over traditional ones. Rev Agric Sci. 2020;8:89-108.
16. De Schutter O, Vanloqueren G. The new green revolution: How twenty-first-century science can feed the world. Solutions. 2011;2(4):33-44.
17. Devi OR, Sarma A, Borah K, Prathibha RS, Tamuly G, Maniratnam K and Laishram B. Importance of zinc and molybdenum for sustainable pulse production in India. Environment and Ecology. 2023; 41(3C): 1853–1859. https://doi.org/10.60151/envec/lcch4556.
18. Gomiero T, Pimentel D, Paoletti MG. Environmental impact of different agricultural management practices: conventional vs. organic agriculture. Crit Rev Plant Sci. 2011;30(1-2):95-124.
19. Wu J, Sardo V. Sustainable versus organic agriculture. In: Sociology, organic farming, climate change and soil science; 2010;41-76.
20. E Birch AN, Begg GS, Squire GR. How agro-ecological research helps to address food security issues under new IPM and pesticide reduction policies for global crop production systems. J Exp Bot. 2011;62(10):3251-61.
21. Nisar S, Rashid Z, Touseef A, Kumar R, Nissa SU, Faheem J, Angrez A, Sabina N, Shabeena M, Tanveer A, Amal S. Productivity of fodder maize (Zea mays L.) SFM-1

under varied sowing dates and nitrogen levels. International Journal of Bio-resource and Stress Management. 2024;15:01-12.

22. Wu J, Sardo V. Sustainable versus organic agriculture. In: Sociology, organic farming, climate change and soil science; 2010;41- 76.
23. Kumari S, Kumar R, Chouhan S, Chaudhary PL. Influence of various organic amendments on growth and yield attributes of mung bean (Vigna radiata L.). International Journal of Plant & Soil Science. 2023;35(12): 124-30.
24. Devi OR, Verma OP, Pandey ST, Laishram B, Bhatnagar A and Chaturvedi P. Correlation of germination, seedling vigour indices and enzyme activities in response to liquid organic kunapajala to predict field emergence in late sown wheat. Environment and Ecology. 2023; 41(3B): 1694–1698. https://doi.org/10.60151/envec/wegd5962.
25. Dwivedi AK, Dwivedi BS. Impact of long term fertilizer management for sustainable soil health and crop productivity: Issues and Challenges. [Research Journal]. 2015;374:49(3).
26. Grigg DB. The agricultural systems of the world: An evolutionary approach. Cambridge University Press. 1974; 343.
27. Swaminathan. 50 years of green revolution: An anthology of research papers. World Scientific Publishing; 2017;1.
28. Verma P, Chauhan A, Ladon T. Site specific nutrient management: A review. J PharmacognPhytochem. 2020;9(5S): 233- 6.
29. Devi, O.R, Ojha, N, Laishram, B., Dutta, S. and Kalita, P. (2023). Roles of Nano-Fertilizers in Sustainable Agriculture and Biosafety. Environment and Ecology, 41(1B): 457—463.
30. Eksoz C, Mansouri SA, Bourlakis M. Collaborative forecasting in the food supply chain: A conceptual framework. Int J Prod Econ. 2014;158:120-35.
31. Ram B, Chouhan S, Tutlani A, Kumar R, Sinha SK, Kumari S. Optimizing Sugarcane Productivity And Soil Nutrient Uptake WithSulphitated Press Mud (SPM), Phosphorus Solubilizing Bacteria (PSB) and Trichoderma viride Integration In Calcareous Soil. Plant Archives. 2024;24(1):122-30.
32. Devi KM, Devi OR, Laishram B, Luikham E, Priyanka E, Singh LR and Babasaheb DV. Effect of Planting Geometry and Nutrient Management on Yield, Economics and Quality of Dwarf Rice Bean (Vignaumbellata) under Rainfed Condition. International Journal of Plant and Soil Science. 2023; 35(9):1–9. https://doi.org/10.9734/ijpss/2023/v35i92897.
33. Shijagurumayum B, Kalpana A, Laishram B and Keisham A. Interactive effect of date of sowing and different source of nitrogen on growth and yield of lentil (Lens culinaris L.) The Pharma Innov. 2022; 11(9):1552-1556.
34. Bhakta I, Phadikar S, Majumder K. State□of□the□art technologies in precision agriculture: A systematic review. J Sci Food Agric. 2019;99(11):4878-88.
35. Devi OR, Laishram B, Singh S, Paul AK, Sarma HP, Bora SS and Devi SS. A Review on Mitigation of Greenhouse Gases by Agronomic Practices towards Sustainable

Agriculture. International Journal of Environment and Climate Change. 2023;13(8):278–287. https://doi.org/10.9734/ijecc/2023/v13i81952.
36. Brouder SM, Gomez-Macpherson H. The impact of conservation agriculture on smallholder agricultural yields: A scoping review of the evidence. AgricEcosyst Environ. 2014;187:11-32.
37. Bruinsma J. World agriculture: Towards 2015/2030: An FAO study. Routledge; 2017.
38. Monyo ES, Varshney RK. Seven seasons of learning and engaging smallholder farmers in the drought-prone areas of sub- Saharan Africa and South Asia through Tropical Legumes. 2007- 2014. international crops research institute for the Semi-Arid tropics; 2016.
39. Chouhan S, Kumari S, Kumar R, Chaudhary PL. Climate Resilient Water Management for Sustainable Agriculture. Int. J. Environ. Clim. Change. 2023;13 (7):411-26.
40. Stagnari F, Ramazzotti S, Pisante M. Conservation agriculture: A different approach for crop production through sustainable soil and water management: A review. Organic Farming, Pest Control and Remediation of Soil Pollutants: Organic farming, pest control and remediation of soil pollutants. 2010; 55-83.
41. Prashar P, Shah S. Impact of fertilizers and pesticides on soil microflora in agriculture. Sustainable Agriculture Reviews. 2016:19:331-61.
42. Laishram B, Singh TB, Kalpana A, Wangkheirakpam M, Chongtham SK and Singh W. Effect of Salicylic Acid and Potassium Nitrate on Growth and Yield of Lentil (Lens culinaris L.) under Rainfed Condition. International Journal of Current Microbiology and Applied Sciences. 2020; 9(11):2779–2791. https://doi.org/10.20546/ijcmas.2020.911.337.
43. Yambem S, Zimik L, Laishram B, Hajarimayum SS, Keisham M and Banarjee L. Response of different rapeseed (Brassica campestris) and mustard (Brassica juncea) varieties on growth and yield under zero tillage conditions. Pharma Innovation. 2020; 9(12):210–212. https://doi.org/10.22271/tpi.2020.v9.i12d.5433.
44. FAO. Sustainable food and agriculture. (n.d.). Food and Agriculture Organization of the United Nations. https://www.fao.org/sustainability/en/.
45. Islam, S. F., & Karim, Z. (2019). Sustainable Agricultural Management Practices and Enterprise Development for Coping with Global Climate Change. In IntechOpen eBooks. https://doi.org/10.5772/intechopen.87000.