



Developing Environmental Resilient Farming with a Focus on *Azolla* as a Fertilizer

Kishore Bellari¹, Bharat Gowda¹, Hubertwell Thabah¹, Lingaraju H. G.^{1*}

¹Department of Environmental Sciences, JSS Academy of Higher Education and Research, Mysuru, India.

*Corresponding author: Lingaraju. H.G. Email: lingarajuhg@jssuni.edu.in

Received 02 Nov 2025

Revised 19 Dec 2025

Accepted 19 Dec 2025

Keywords:

- ✓ *Azolla*
- ✓ Climate change
- ✓ Inorganic
- ✓ Organic
- ✓ Green manure

Citation: Bellari K., Bharat G., Hubertwell T., Lingaraju H.G. (2026). Developing Environmental Resilient Farming with a Focus on *Azolla* as a Fertilizer, *J. Mater. Environ. Sci.* 17(1), 32-46

Abstract: Global agriculture faces enormous obstacles because of climate change, which also raises questions about financial stability, environmental damage, and food security. This paper examines the intricate relationship between agriculture and climate change, with a particular focus on India, a nation highly vulnerable to global warming. Since considerable drops in crop production and disturbances to farming operations are expected, prompt intervention is imperative. Exploration into alternatives such as organic manure, natural agriculture, and *Azolla* as a biofertilizer has been spurred by the unsustainable and ecologically harmful nature of traditional agricultural systems that rely on chemical fertilizers. The nitrogen-fixing aquatic fern *Azolla* provides crops with a sustainable source of nutrients, improving soil health and lowering dependency on artificial fertilizers. Greenhouse gas emissions are also lessened by its capacity to store carbon dioxide from the atmosphere. Issues such as labor-intensive cultivation and a lack of research persist despite its advantages. Soil fertility, biodiversity, and agricultural yields can all be enhanced by incorporating *Azolla* into agriculture. To maintain food security and climate change resilience, the review emphasizes the necessity of creative thinking and sustainable methods.

1. Introduction

Climate change is one of the most pressing global issues of today (Santos *et al.* 2020). Significant variations in the average values of meteorological parameters, such as precipitation and temperature, were estimated over a lengthy time (Malhi *et al.*, 2021). Human actions, including the use of fossil fuels and land use changes, are responsible for most of the observed warming (0.1°C per decade) over the past 50 years (Karimi *et al.*, 2018). The possible implications for urban areas are receiving increased attention. Over the next 30 years, cities are predicted to house more than 60% of the world's population, up from over 50% currently (Wilby, 2006). The agriculture sector's dependency on climate change is a key problem for economic growth, as most of the country's population lives in rural regions and works in agricultural and non-agricultural fields. Farmers are continuously looking for strategies to adapt to changing weather and climate circumstances Figure 1 (Serdeczny *et al.* 2017). However, environmental and global climate change have broadened the scale required for farmers to design and execute resilience methods (Chandio *et al.* 2020). India is among the most affected nations in terms of

climate change and natural hazards due to its scarce arable land, large population, reliance on monsoon-dependent agriculture, and limited technological and financial development for climate change adaptation (Malhi *et al.* 2021). By 2050, global food consumption is expected to increase by 70-85% as the world's population exceeds 9 billion (Gallina *et al.* 2016). According to the Food and Agriculture Organisation's 2016 estimates, if present Greenhouse gas emissions and climate change continue, the main cereal crop output would drop by 20-45% in maize, 5-50% in wheat, and 20-30% in rice by 2100 (Arora 2019). Climate change is anticipated to significantly impact Indian agriculture by reducing yields of wheat, soybean, mustard, groundnut, and potato by 3-7% for every one-degree increase in temperature (Dhanya and Ramachandran 2016). "Next generation Green Revolution" is needed to ensure future food security (Bachev 2018). Radical new thoughts and practices are required to achieve more sustainable agricultural development (Dhankher and Foyer 2018).

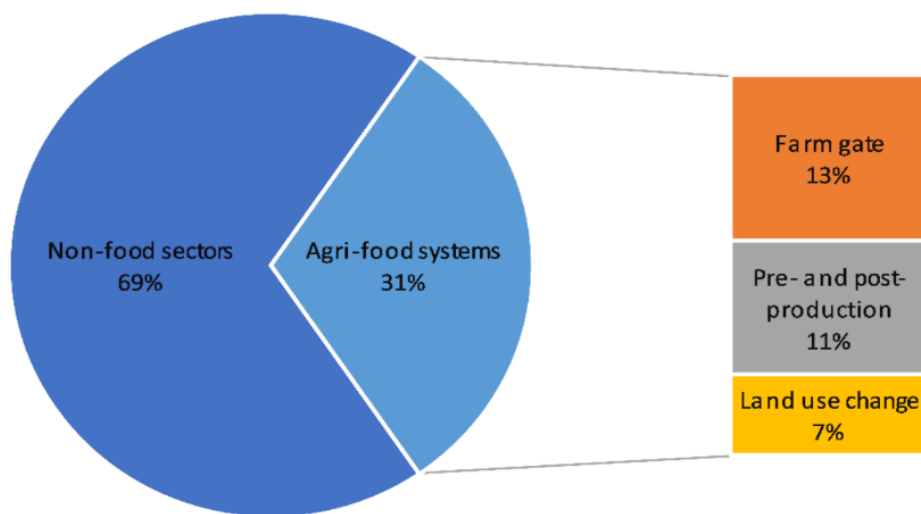


Figure 1: Contribution of agri-food systems and non-food sectors to global greenhouse gas emissions (Holka *et al.*, 2022)

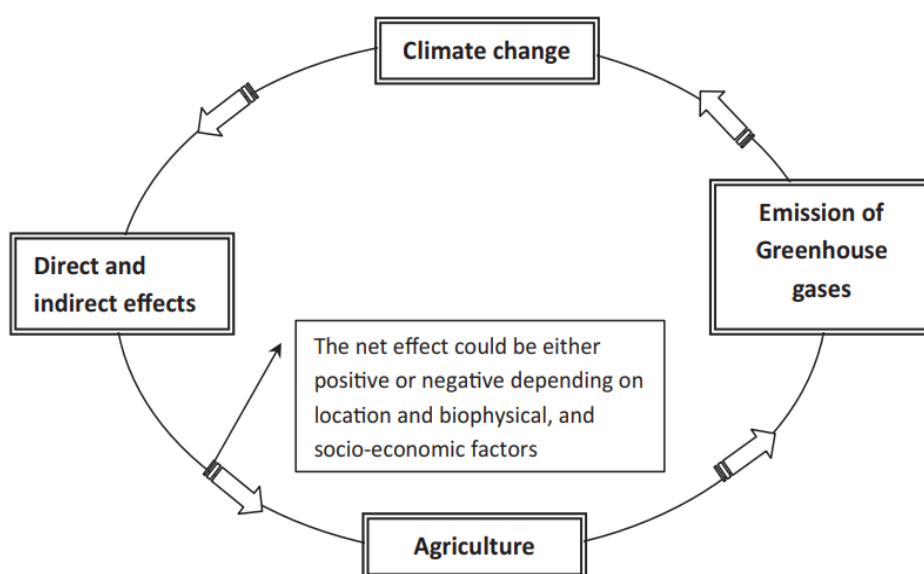


Figure 2: Interrelationship between climate change and agriculture (Tripathi and Mishra 2017).

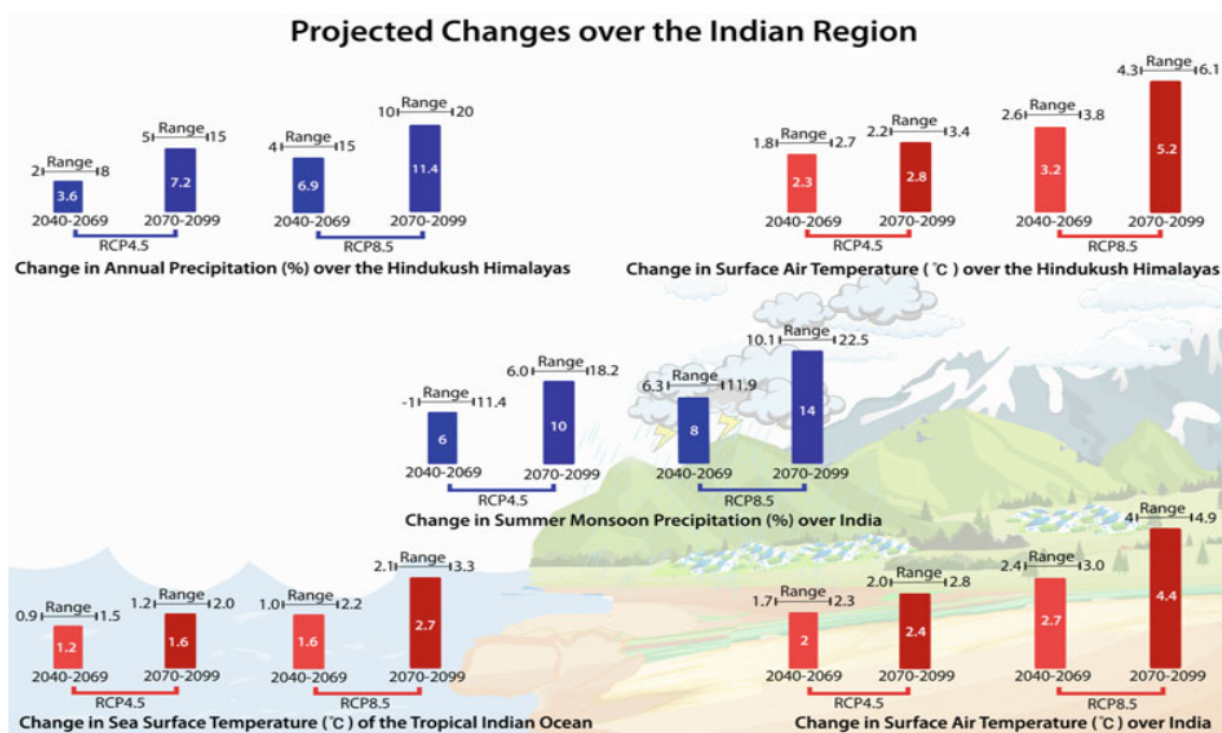


Figure 3: Changes in the Indian region (Krishnan et al.).

2. Backdrops of Inorganic Fertilizers

Pesticides and inorganic fertilizers serve a crucial role in agricultural growth, reducing product losses and improving yield and food quality. During World War II (1939-1945), pesticide research accelerated due to the need to boost food production and combat insect-borne illnesses. (Karimi et al. 2018). The growing use of inorganic fertilizer contributed to the 1960s Green Revolution, which improved food output and reduced hunger worldwide. Meeting food security, tackling climate change, and preventing environmental and natural resource degradation are among the primary challenges the agriculture sector faces in achieving the Sustainable Development Goals (SDGs) and the Paris Agreement to limit global temperature rise to 2°C (Prakash Aryal et al., 2021). And fertilizer aggregation, soil erosion, soil and water contamination, genetic erosion, nutrient leaching, and agrobiodiversity loss are all negative environmental consequences of intensive chemical fertilizer usage. (Ostadi et al. 2020). Efficient fertilization methods are crucial for meeting global demand, as excessive use of inorganic fertilizers poses environmental problems. Agricultural output has increased, but it is also a major contributor to environmental degradation (Rahman and Zhang 2018). Research indicates that relying solely on inorganic or organic fertilizers does not guarantee long-term production. (Islam et al. 2017). Organic manure alone may not fulfil plant requirements due to its poor nutritional content, are human carcinogens. (Shamsuddoha and Haque 2017). The EPA's Office of Pesticide Programs reports that most pesticides include chemicals linked to cancer risk. Overuse of inorganic fertilizers can lead to nutritional imbalances, limiting the absorption of key nutrients and causing soil acidity, resulting in lower crop yields. (Sharma 2017). They are costly, and the fertilisers include harmful substances that might harm the skin and respiratory system. The Overuse of fertilisers harms plants and lowers soil fertility. (Islam et al. 2017). The fertilisers leach into rivers, leading to eutrophication. Long-term usage lowers microbial activity and alters soil pH. (ALnaass et al., 2021).

The extensive lysimeter setup and treatment selection resulted in a unique and useful outcome. (Zhao *et al.* 2016). This study examines the influence of animal manures and inorganic fertilisers on nitrate leaching and yield in a long-term crop rotation. (Basso and Ritchie 2005). While the green revolution increased food production significantly, it did not prioritise sustainability. Using chemical fertilizers for agricultural development might lead to poor soil quality, water contamination, and an unsustainable financial load. (Mazid and Khan 2014).

3. Organic Fertilizers: Enhancing Soil Health and Promoting Sustainable Food Systems.

Controlling the use of chemical fertilizers involves both technological and policy measures. Technical methods such as soil testing, controlled-release fertilizers, crop rotation, organic fertilizers, and recycled agriculture can help minimize chemical fertilizer consumption. (Wang *et al.* 2018). Organic farming has gained popularity over the last two decades, owing to its high-quality products, high cost, and limited market availability of inorganic fertilizers, particularly in developing nations such as Asia, Africa **Figure 4** (Lorenz and Lal 2016). Certified organic grains are more valuable than inorganic products. (Hammad *et al.* 2020). Fertilizers, which contain live or latent cells of efficient nitrogen-fixing, phosphate-solubilising, or cellulolytic micro-organisms, are applied to seed, soil, or composting areas to increase the number of these micro-organisms and accelerate microbial processes that enhance nutrient availability for plants. (Rajvir and Sudhir Kumar 2013; Sabbahi *et al.*, 2022).

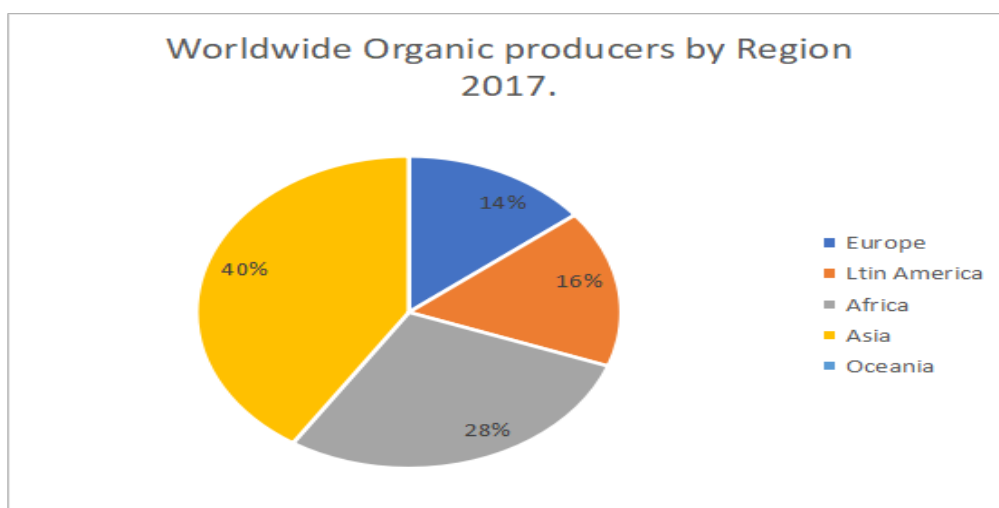


Figure 4: Global Organic Consumers by Region 2017 (Mukherjee, Konar, and Ghosh 2022).

Application of organic fertilizers such as animal dung, sawdust, and others, or a combination of organic and inorganic fertilisers, might be an alternate option for reducing inorganic fertilizer use **Figure 5** (Martínez-Alcántara *et al.* 2016). Organic fertilizers, as opposed to inorganic fertilizers, preserve soil quality, enhance soil organic matter, and improve soil physical and chemical qualities via the breakdown of its constituents. (Kakar *et al.* 2020). Organic fertilizers deliver some advantages to improve agricultural activity and enhance soil quality by improving their microbiological, physicochemical, and biochemical qualities. (Muktamar *et al.* 2017). They restore soil fertility by restoring organic matter loss over short and extended periods. (Thomas *et al.* 2019). They improve soil nutrients, promoting healthy growth with little nutrient-dense fertilisers. (Randive *et al.*, 2021) Achieve sustainable agricultural production while minimizing environmental impact and crop yields. (Shaji *et al.*, 2021). Organic agriculture faces significant hurdles in transitioning from a solely agricultural perspective to an agri-food system perspective, (Meemken and Qaim 2018). Which includes Producing

enough healthy, safe, and affordable food for 9-11 billion people and reducing pollutants and greenhouse gas emissions associated with food production, processing, trade, and consumption & creating sustainable food chains using renewable energy and recycled nutrients and it is addressing climate change and reducing greenhouse gas emissions and Preserving soils, water, air, biodiversity, and landscapes and it Consider current and evolving ethics, dietary habits, lifestyles, and customer demands. (Rahmann *et al.* 2017) Farming will generate a healthy natural environment and ecology for both the present and future generations. (Mazid and Khan 2014).

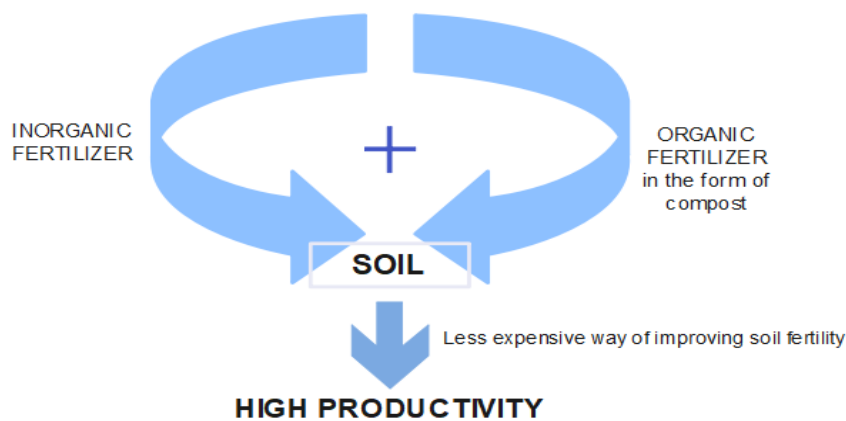


Figure 5: The impact of blending organic and inorganic fertilizer on soil fertility and productivity (Roba 2018).

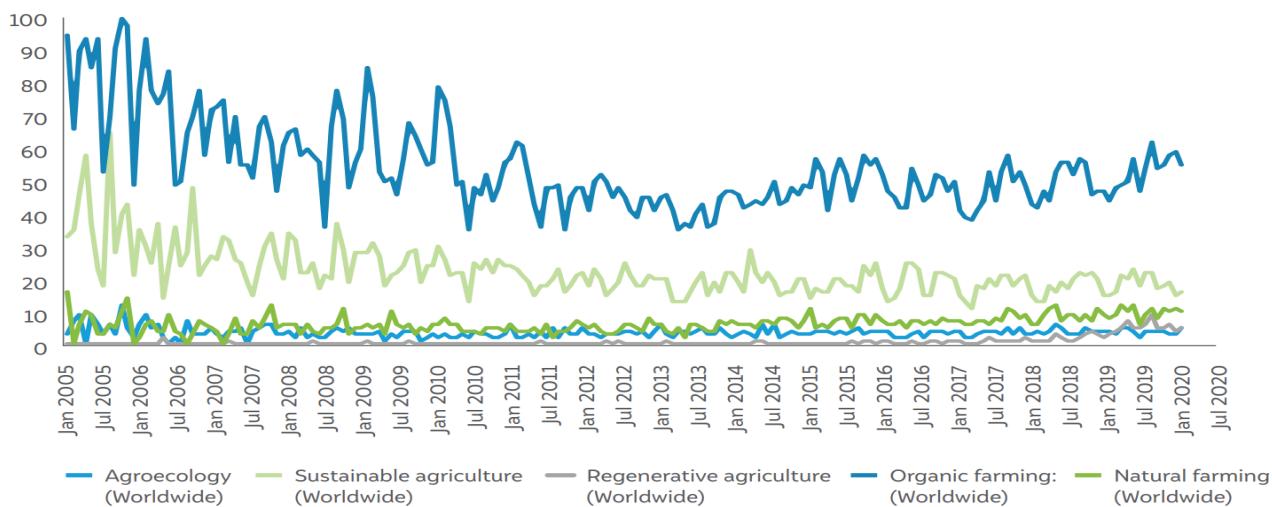


Figure 6: Shows how organic farming was rapidly growing worldwide (Rahmann *et al.* 2017).

4. Green Manure: A Sustainable Strategy for Soil Health and Climate Resilience.

Agriculture has seen changes in farm size, marketing techniques, and biological and economic variety throughout the last century. **Figure 6** increasing reliance on nonrenewable resources and susceptibility to urbanization, climate change, and unpredictable global markets (Ben-Laouane *et al.* 2020). As a result, producers, consumers, government agencies, and academics are increasingly interested in economically viable alternatives that rely on ecological and biological processes, on-farm resources, and diversity (Cherr, Scholberg, and McSorley 2006) The green manure treatment exhibited a considerable favorable influence on the biomass of microbial organisms, carbon levels, and enzyme

activity in the soil (Peigné *et al.* 2016; Haoufazane *et al.*, 2025). Manure can reduce the environmental dangers associated with NO₃ leaching. Dhaincha (*Sesbania aculeata*) and sun hemp (*Crotalaria juncea*) are well-known in South Asia for their capacity to form nodules, fix nitrogen, and generate relatively significant amounts of organic matter (Islam *et al.* 2019). The use of green manure and cover crops would require little or no monetary expenditure. Farmers should be able to generate their seeds year after year, and crops should be resistant to diseases and insects (Karyoti *et al.* 2018; Laita *et al.*, 2024). Ideally, Green manure and cover crops can save farmers money (Cao *et al.*, n.d.2017). Fertilizers are used extensively to improve agricultural output and quality. Using excessive mineral fertilizer can result in significant nutrient losses from the soil, negatively impacting the quality of surface and groundwater. Green manure adds a significant quantity of nitrogen to the soil, but it releases nutrients at a slower pace. Additionally, N-fixing bacteria release N over time. These mechanisms provide a consistent supply of nitrogen for successive harvests **Figure 7** (Mwangi *et al.*, 2024). Green manure crops boost soil nutrients by improving nutrient absorption efficiency, microbial biomass, water retention capacity, and organic matter. Additionally, it reduces soil erosion and nitrogen levels (Tao *et al.* 2017). Using high-quality green manure crops, such as legumes, with low lignin content and a low carbon-to-nitrogen ratio, improves nutrient efficiency by releasing nutrients faster to the plant (Gill *et al.*, 2020). Annual legume green manures in the Black soil zone can generate up to 5000 kg ha⁻¹ dry matter. In drier places like the Brown soil zone, yearly green manure biomass output might approach 2500 kg ha⁻¹ (Martens and Entz 2011). The crop rotation will also play a major role in the growth of plants using green manure as fertilizers to address climate issues. We should develop crop rotation technologies, create policies tailored to local conditions, refine subsidies, train farmers, and strengthen crop rotation supervision. Crop rotation has the potential to enhance cropping system resilience to climate (Amit Kumar 2015).

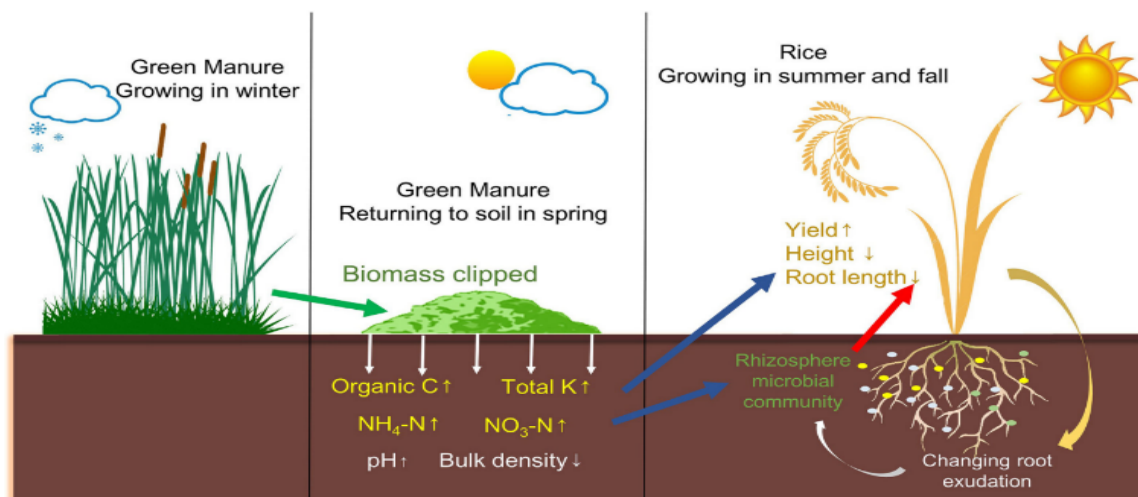


Figure 7: A conceptual model of how long-term green manure affects paddy crop processes in ecosystems (Zhang *et al.* 2017).

Some strengths of growing green manure are that Farmers prefer green manure to compost or fertilizers due to their perceived benefits. Green manure offers several benefits, including increased soil fertility, improved soil structure, food for earthworms, no risk to soil health, increased biodiversity of beneficial bacteria, and low cost (Dhadse and Mater 2024). The Weakness is that green manure is required in large quantities. Nutrients are only available after decomposition, which can take up to 2-3 months. There are some opportunities for growing green manure (Piotrowska-Długosz and Wilczewski 2020).

Green leaves and manure are inexpensive, organic, and widely available. Some green manure species could reduce soil-borne fungal diseases (Calçada *et al.*, 2019). Green manure can help restore salty soil. One challenge of growing green manure is that Termites have become an issue in alluvial soils. Lack of study on green manure crops, and Limited supply of high-quality green manure seeds (Couëdel *et al.*, 2018).

5. *Azolla*: A Multifunctional Biofertilizer for Sustainable Agriculture and Climate Mitigation

The name *Azolla*, which refers to the incapacity of plants to endure in arid environments, is derived from two Greek words: Azo (to burn) and Allyo (to kill). *Azolla* is a small-leafed floating plant and aquatic fern. It belongs to the genus *Azolla* and family Azollaceae. Rhizosperma and Euazolla are the two subgenera of *Azolla*. Rhizosperma has just two species, *A. pinnata* and *A. nilotica*, whereas Euazolla contains five species: *A. caroliniana* Willd., *A. mexicana* Presl., *A. microphylla* Kaulf., *A. rubra*, and *A. filiculoides*. (Sapna and Mater 2022) The importance of *Azolla* as organic manure in rice was first demonstrated in North Vietnam in 1957 and subsequently introduced in the USA, Indonesia, Japan, Philippines, China, and India (Thapa and Poudel 2021). With concern for environmental sustainability, the aquatic fern *Azolla* is a well-established biotechnology product with the potential for global use (Korsa *et al.*, 2024a). It has a variety of applications and has recently acquired popularity as a biofertilizer (Yadav *et al.* 2014). This study aims to investigate the possible use of *Azolla* as a fertilizer for soil-grown vegetable crops (Jama *et al.* 2023). Using *Azolla* compost for agricultural purposes is seen as good environmental practice due to its beneficial effect on reducing methane emissions and global warming (Gowda 2023). The application of *Azolla* as a biofertilizer provides natural source nutrients and has tremendous potential to improve soil health and boost yield sustainability. *Azolla*, a free-floating, widely distributed aquatic fern, offers significant potential as a Nitrogen source in rice production. Phytoplankton like *Azolla* might be useful to meet the need to some extent because it takes very little time for its growth and multiplication, and it is easily compostable too. *Azolla* takes 2 to 3 days to double its mass through multiplication and growth (Kumar and Shahi 2016). Amendments used in agriculture have a significant positive influence on agricultural productivity (Ahmed Noman and Tariq Humna 2021). Approximately 65-80% of *Azolla* sp. N was generated 30 days (about 4 and a half weeks) before rice transplantation, with 20-35% produced 15-20 days (about 3 weeks) after (Seleiman *et al.* 2022).

Table 1: Taxonomical Classification of *Azolla* (Lastrucci *et al.* 2019).

S/N	Kingdom	Plantae
1	Clade	Tracheophytes
2	Division	Polypodiophyta
3	Class	Polypodiopsida
4	Order	Salviniales
5	Family	Salviniaceae
6	Genus	<i>Azolla</i>



Figure 8 : *Azolla pinnata* (Said *et al.* 2023).

Due to the presence of the heterocyst's cyanobacterium *Anabaena azollae*, which is restricted to the dorsal leaf cavity of the fern, *Azolla* can fix nitrogen from the atmosphere biologically (Korsa *et al.*, 2024b). The dorsal leaf lobe's enfolding of the adaxial epidermis creates this hollow. **Figure 8** Massive amounts of *Azolla* plants captured large amounts of ambient CO₂ and transformed it straight into *Azolla* biomass (Izdzuani *et al.* 2021). The absorbed carbon is kept when *azolla* biomass is added to soils or sediment, avoiding its release as a greenhouse gas back into the environment. By storing carbon, CO₂ emissions can be reduced, and the impacts of climate change can be lessened (Pampana *et al.* n.d). *Azolla* is a tiny water fern that can thrive without combined nitrogen because of nitrogen fixation by symbiotic cyanobacteria (Karichu *et al.* 2022). It has been utilized as green manure for numerous crops (Chanapanchai *et al.* 2025). *Azolla* has special applications for use, such as green feedstock and as composting manure, because of its nitrogen concentration, which can boost crop growth.

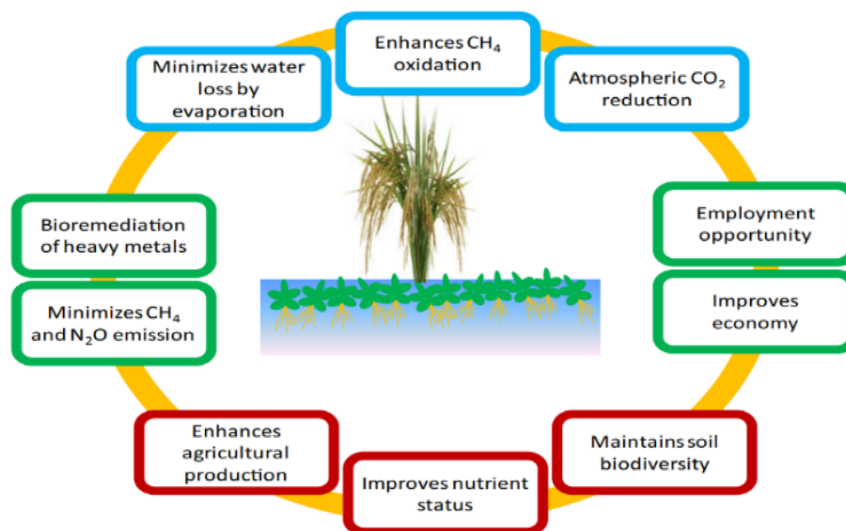


Figure 9: Agricultural use of the socioeconomic and ecological services provided by *Azolla* (Kollah, Patra, and Mohanty 2016).

Azolla pinnata has several advantages, including biofertilizer, human food, animal and fish feed, and medical additives (Marzouk *et al.* 2023). The use of animal dung as a fertilizer for *Azolla pinnata* reduces production costs, although the type and rate of manure application are unknown (Utomo *et al.* 2019). The managed microbial aerobic breakdown and stabilization of organic substrates under circumstances that allow thermophilic microorganisms to generate high temperatures, resulting in a

stable product devoid of pathogens, viable weed seeds, and suitable crops (Jumadi *et al.* 2014). *Azolla* has been extensively researched as a green manure or bio-fertilizer for crops, but its potential for providing amino acids and protein in cattle feed has received little attention from researchers (Marzouk *et al.* 2024). *Azolla* is used as organic manure in certain areas of Assam, India. However, nothing is known about the benefits of *Azolla* compost. Composted *Azolla* is a sustainable organic source that can help reduce GHG emissions from rice fields **Figure 9** although it is currently only used in a few regions of northeast India (Marzouk *et al.* 2023). It is important to precisely assess the influence of *Azolla*-compost on the CH₄-induced global warming potential of rice (Shahid *et al.* 2021). The *Azolla*-*Anabaena* symbiosis effectively recycles non-nitrogen-bearing nutrients through rivers into soil. (Moshia 2018). In this recycling system, as well, atmospheric nitrogen accounts for a significant portion of the total nitrogen given to the soil. (Kumar 2018). This suggests that other nutrients are recycled when nitrogen is augmented. (da Silva *et al.* 2022). It was discovered that *Azolla* improved nutrient cycling, increased microbial biomass, and improved organic carbon. (Adnyana, Bimantara, and Roni 2025). It appears that adding *Azolla* requires more labour, and it is unlikely that *Azolla* biomass can be maintained, given the ongoing decline in soil quality and the present demand for N fertilizers. (Katole, Lende, and Patil. 2020). Since the adoption of *Azolla* presents a significant possibility for rice production, strategic activities should concentrate on, among other things. (Kollah *et al.* 2016). Data points to the possibility that *Azolla* species were crucial to the global cooling that occurred during the middle Eocene, also known as the " *Azolla* Event " (Marzouk *et al.* 2023). The results of this earlier study support continuing investigations into whether *Alloa*'s exceptional capacity to absorb carbon may be used to reduce greenhouse gas emissions and the effects of global warming (Chaudhary *et al.* 2025). Additionally, it was suggested that the *Azolla* species may be used on Mars in conjunction with rice, beans, and soybeans as a component of a vegetarian diet. This super plant has virtually limitless applications. (Gunawardana 2019).

Conclusion

In summary, there is no denying the potential of *Azolla* to promote resilience to climate change in agricultural operations, especially when applied as fertilizer. It is clear from a thorough examination that *Azolla* provides farming practices with a variety of advantages, from improved soil fertility to decreased greenhouse gas emissions. The possibility of supporting environmentally friendly farming practices is highlighted by its capacity to fix nitrogen, inhibit weed growth, and offer an environmentally friendly replacement for synthetic fertilizers. Moreover, the incorporation of *Azolla* into agricultural methods is consistent with more general objectives of sustainability, helping to alleviate the consequences of global warming and lessen environmental deterioration. Its contribution to biodiversity and better soil health highlights how important it is to the shift to more resilient agricultural systems. Notwithstanding the significant advantages of *Azolla*, it is imperative to recognise the possible obstacles and constraints linked to its execution, including the efficient use of water assets and the mitigation of potential invasiveness in certain ecosystems. Overall, studies on *Azolla* and its use as fertilizer show that it has an opportunity to transform agricultural methods and increase their resistance to the environment. To realize *Azolla*'s greatest potential in organic farming and build a more resilient food production system for coming generations, further research is necessary, as is legislative backing and realistic execution techniques.

Acknowledgement The authors gratefully acknowledge the valuable academic support and guidance provided by the Department of Environmental Sciences, JSS Academy of Higher Education and

Research, Mysuru. The constructive inputs and scholarly environment offered by the faculty greatly contributed to the completion of this review.

Disclosure Statement Conflict of Interest: The authors declare that there are no conflicts of interest regarding the publication of this article. **Compliance with Ethical Standards:** This review article does not involve any experiments on human or animal subjects. All sources used have been duly cited, and the work adheres to ethical standards for scholarly publishing.

References

- Amit Kumar, M. P. Sharma. 2015. "Assessment of Carbon Stocks in Forest and Its Implications on Global Climate Change." *Journal of Materials and Environmental Sciences*. 6 (12) (2015) 3548-3563
- Adnyana, I. Made, Putu Oki Bimantara, and Ni Gusti Ketut Roni. 2025. "Enhancing Soil Fertility Through Azolla Incorporation: Impacts on Nitrogen Cycling and Cation Exchange Capacity." *Organic Farming* 11(1), 1–12. <https://doi.org/10.56578/OF110101>
- Ahmed Noman, Humna T. 2021. "Azolla as Waste Decomposer and Bio-Fertiliser: A Review." *Journal of Applied Research in Plant Sciences* 2(1), 108–16. <https://doi.org/10.38211/JOARPS.2021.2.1.14>
- Alnaass, Nuri Salem, Hossean Khalifa Agil, And Hamza Khalifa Ibrahim. 2021. "Use of Fertilizers or Importance of Fertilizers in Agriculture." *International Journal of Advanced Academic Studies* 3(2), 52–57. <https://doi.org/10.33545/27068919.2021.V3.I2A.770>
- Arora, Naveen K. 2019. "Impact of Climate Change on Agriculture Production and Its Sustainable Solutions." *Environmental Sustainability* 2(2), 95–96. <https://doi.org/10.1007/s42398-019-00078-w>
- Bachev, Hrabrin. 2018. *Institutional Environment and Climate Change Impacts on Sustainability of Bulgarian Agriculture. Vol. 24*.
- Basso, Bruno, And Joe T. Ritchie. 2005. "Impact of Compost, Manure and Inorganic Fertilizer on Nitrate Leaching and Yield for a 6-Year Maize-Alfalfa Rotation in Michigan." *Agriculture, Ecosystems and Environment* 108(4), 329–41. <https://doi.org/10.1016/j.agee.2005.01.011>
- Ben-Laouane, R., Baslam M., Ait-El-Mokhtar M., Anli M., Boutasknit A., Ait-Rahou Y., Toubali S., Mitsui T., Oufdou K., Wahbi S., Meddich A. 2020. "Potential of Native Arbuscular Mycorrhizal Fungi, Rhizobia, and/or Green Compost as Alfalfa (Medicago Sativa) Enhancers Under Salinity." *Microorganisms* 8(11), 1–27. <https://doi.org/10.3390/microorganisms8111695>
- Calçada, Dario Brito, Solange Oliveira Rezende E Mauro Sergio Teodoro. 2019. "Analysis of Green Manure Decomposition Parameters in Northeast Brazil Using Association Rule Networks." *Computers and Electronics in Agriculture* 159, 34–41. <https://doi.org/10.1016/j.compag.2019.02.013>
- Cao, Wei-Dong, Bao Xing-Guo, X. U. Chang-Xu, Nie Jun, Gao Ya-Jun, Ming-Jian Geng N.D. 2017. Reviews and Prospects on Science and Technology of Green Manure in China, *Journal of Plant Nutrition and Fertilizers* 23(6), 1450–61. <https://doi.org/10.11674/zwyf.17291>
- Chanapanchai, Siriyaporn, Wahdan Fitriya, Ida Bagus Made Artadana, And Kanyaratt Supaibulwatana. 2025. "Important Role and Benefits of Azolla Plants in The Management of Agroecosystem Services, Biodiversity, and Sustainable Rice Production in Southeast Asia." *Journal of Integrative Agriculture* 24(8), 3004–23.
- Chandio, Abbas Ali, Yuansheng Jiang, Abdul Rehman, Abdul Rauf. 2020. "Short and Long-Run Impacts of Climate Change on Agriculture: An Empirical Evidence from China." *International Journal of Climate Change Strategies and Management* 12(2), 201–21. <https://doi.org/10.1108/IJCCSM-05-2019-0026>
- Chaudhary A., Sah P.K., Paudel S., Timsina A. 2025. Effects of Azolla Incorporation Timing on Growth and Yield Performance of Spring Rice (*Oryza Sativa* L.). *Turkish Journal of Agriculture - Food Science and Technology* 13(S1), 2420–28. <https://doi.org/10.24925/TURJAF.V13iS1.2420-2428.7990>
- Cherr, C. M., J. M. S. Scholberg, And R. Mcsorley. 2006. "Green Manure Approaches to Crop Production: A

- Synthesis.” *Agronomy Journal* 98(2):302–19. <https://doi.org/10.2134/agronj2005.0035>
- Couëdel, Antoine, Lionel Alletto, Hélène Tribouillois, Et Eric Justes. 2018. “Cover Crop Crucifer-Legume Mixtures Provide Effective Nitrate Catch Crop and Nitrogen Green Manure Ecosystem Services.” *Agriculture, Ecosystems and Environment* 254, 50–59. <https://doi.org/10.1016/j.agee.2017.11.017>
- Dhadse, S., And J. Mater. 2024. “Utilization of Fly Ash in Agriculture: Perspectives and Challenges.” *J. Mater. Environ. Sci* 2024(7):1038–50. <http://Www.Jmaterenvirosci.Com>.
- Dhankher, Om Parkash, And Christine H. Foyer. 2018. “Climate Resilient Crops for Improving Global Food Security and Safety.” *Plant Cell and Environment* 41(5), 877–84. <https://doi.org/10.1111/pce.13207>
- Dhanya, P., And A. Ramachandran. 2016. “Farmers’ Perceptions of Climate Change and The Proposed Agriculture Adaptation Strategies in a Semi-Arid Region of South India.” *Journal Of Integrative Environmental Sciences* 13(1), 1–18. doi.org/10.1080/1943815X.2015.1062031
- Gallina, Valentina, Silvia Torresan, Andrea Critto, Anna Sperotto, Thomas Glade, and Antonio Marcomini. 2016. “A Review of Multi-Risk Methodologies for Natural Hazards: Consequences and Challenges for A Climate Change Impact Assessment.” *Journal Of Environmental Management* 168, 123–32. <https://doi.org/10.1016/j.jenvman.2015.11.011>
- Gill, Kajal, Sandeep Sandhu, Manjeet Mor, Tarun Kalmodiya, And Maninder Singh. N.D. Role Of Green Manuring in Sustainable Agriculture: A Review. Vol. 7.
- Gowda, Bharat. 2023. “In Situ Phytoremediation of Azo Dyes (Methylene Blue) By the Plant *Azolla Pinnata*.” *Azolla Pinnata, J. Mater. Environ. Sci* 14(11), 1456–67. <http://Www.Jmaterenvirosci.Com>.
- Gunawardana, Dilantha. 2019. “An Exploration of Common Greenhouse Gas Emissions by the Cyanobiont of the *Azolla*–*Nostoc* Symbiosis and Clues as to Nod Factors in Cyanobacteria.” *Plants* 8(12), 587. <https://doi.org/10.3390/plants8120587>.
- Haoufzane, C., Zaaboul, F., Monfalouti, H.E., Jodeh S., Azzaoui K., Hammouti B., Tihmmou R., Salghi R. & Badr Eddine Kartah B.E. (2025). Enhanced removal of C.I. direct black 80 by phosphoric acid activated plant biomass supported by DFT insights. *Sci Rep* 15, 40134 <https://doi.org/10.1038/s41598-025-23886-z>
- Hammad, Hafiz Mohkum, Abdul Khaliq, Farhat Abbas, Wajid Farhad, Shah Fahad, Muhammad Aslam, Ghulam Mustafa Shah, Wajid Nasim, Muhammad Mubeen, And Hafiz Faiq Bakhat. 2020. “Comparative Effects of Organic and Inorganic Fertilizers on Soil Organic Carbon and Wheat Productivity Under an Arid Region.” *Communications in Soil Science and Plant Analysis* 51(10), 1406–22. <https://doi.org/10.1080/00103624.2020.1763385>.
- Holka, Małgorzata, Jolanta Kowalska, And Magdalena Jakubowska. 2022. “Reducing Carbon Footprint of Agriculture—Can Organic Farming Help to Mitigate Climate Change?” *Agriculture (Switzerland)* 12(9). <https://doi.org/10.3390/agriculture12091389>.
- Islam, M., Sumiya Islam, Ayasha Akter, Md Rahman, Dilip Nandwani. 2017. Effect of Organic and Inorganic Fertilizers on Soil Properties and the Growth, Yield and Quality of Tomato in Mymensingh, Bangladesh.” *Agriculture* 7(3), 18. <https://doi.org/10.3390/agriculture7030018>.
- Islam, Md Moshui, Urmi T.A., Rana M.S., Saiful Alam M., Moynul Haque M. 2019. “Green Manuring Effects on Crop Morpho-Physiological Characters, Rice Yield and Soil Properties.” *Physiology and Molecular Biology of Plants* 25(1), 303–12. <https://doi.org/10.1007/S12298-018-0624-2>.
- Izdzuani, Mohamad, Mohamad Khair, Elisa Azura Azman, Roslan Ismail, Muhammad Naim Fadzli, Abdul Rani, And Elisa Azura Azman. 2021. “Effect of the Biofertilizer (*Azolla Pinnata*) in Combination with Inorganic Fertilizers on Growth and Yield of Rice.” *Grassroots Journal of Natural Resources* 4(4), 59–75. <https://doi.org/10.33002/NR2581.6853.040405>
- Jama, Aisha, Dwi P. Widiastuti, Sutarman Gafur, And Jessica G. Davis. 2023. “*Azolla* Biofertilizer Is an Effective Replacement for Urea Fertilizer in Vegetable Crops.” *Sustainability (Switzerland)* 15(7), 6045. <https://doi.org/10.3390/SU15076045>
- Jumadi, Oslan, St Fatmah Hiola, Yusminah Hala, Jeanette Norton, And Kazuyuki Inubushi. 2014. “Influence

- of Azolla (*Azolla Microphylla* Kaulf.) Compost On Biogenic Gas Production, Inorganic Nitrogen and Growth of Upland Kangkong (*Ipomoea Aquatica* Forsk.) In A Silt Loam Soil.” *Soil Science and Plant Nutrition* 60(5), 722–30. <https://doi.org/10.1080/00380768.2014.942879>
- Kakar, Kifayatullah, Tran Dang Xuan, Zubair Noori, Shafiqullah Aryan, And Gulbuddin Gulab. 2020. Effects of Organic and Inorganic Fertilizer Application on Growth, Yield, And Grain Quality of Rice. *Agriculture (Switzerland)* 10(11), 1–11. <https://doi.org/10.3390/AGRICULTURE10110544>
- Karichu, Mwihaiki J., Boniface K. Ngarega, Guy E. Onjalalaina, Peris Kamau, And Emily B. Sessa. 2022. “The Potential Distributions of African Azolla Species and Their Implications for African Wetland Ecosystems for The Future.” *Ecology And Evolution* 12(8). <https://doi.org/10.1002/ECE3.9210>
- Karimi, Vahid, Ezatollah Karami, And Marzieh Keshavarz. 2018. “Climate Change and Agriculture: Impacts and Adaptive Responses in Iran.” *Journal Of Integrative Agriculture* 17(1), 1–15. [https://doi.org/10.1016/S2095-3119\(17\)61794-5](https://doi.org/10.1016/S2095-3119(17)61794-5)
- Karyoti, Aikaterini, Dimitris Bartzialis, Maria Sakellariou-Makrantonaki, And Nikolaos Danalatos. 2018. Effects Of Irrigation and Green Manure on Corn (*Zea Mays* L.) Biomass and Grain Yield. Vol. 18.
- Katole, Shrikant B., Shweta R. Lende, And S. S. Patil. N.D. A Review on Potential Livestock Feed: Azolla. www.jakraya.com/Journa/Lri.
- Kollah, Bharati, Ashok Kumar Patra, And Santosh Ranjan Mohanty. 2016. “Aquatic Microphylla Azolla: A Perspective Paradigm for Sustainable Agriculture, Environment and Global Climate Change.” *Environmental Science and Pollution Research* 23(5), 4358–69. <https://doi.org/10.1007/S11356-015-5857-9>
- Korsa, Gamachis, Digafe Alemu, And Abate Ayele. 2024a. “Azolla Plant Production and Their Potential Applications” Edited By M. Serrano. *International Journal of Agronomy* 2024, 1–12. <https://doi.org/10.1155/2024/1716440>
- Korsa, Gamachis, Alemu D., Ayele A. 2024b. Azolla Plant Production and Their Potential Applications, *International Journal of Agronomy* 2024, 1-12. <https://doi.org/10.1155/2024/1716440>
- Krishnan, R., J Sanjay, Chellappan, Gnanaseelan . Milind Mujumdar, Ashwini Kulkarni, And Supriyo Chakraborty. N.D. Assessment of Climate Change Over the Indian Region A Report of The Ministry of Earth Sciences (Moes), *Government of India*.
- Kumar, Bhupendra, And D. K. Shahi. 2016. Effect Of Azolla as Green Manure on Soil Properties And Grain Yield Of Rice In Acid Soil Of Jharkhand. Vol. 18.
- Kumar, Gulshan. 2018. Integrated Farming Strategies for Climatic Resilient Agriculture Under Rainfed Conditions In Northwest Himalayan Regions, *J. Biol. Chem. Chron.* 4(1), 26-41,
- Laita, M., Sabbahi, R., Azzaoui, K., Hammouti, B., Nasri, H., Messaoudi, Z., Benkirane, R., Aithaddou, H. (2024). Optimizing water use and crop yield with deficit irrigation techniques: A comprehensive overview and case study from Morocco. *Multidisciplinary Reviews*, 7 Issue 4, e2024074 <https://www.malque.pub/ojs/index.php/mr/article/view/1981>
- Lastrucci, Lorenzo, Graziana Fiorini, Livia Lunardi E Daniele Viciani. 2019. “Herbarium Survey On The Genus Azolla (Salviniaceae) In Italy: Distributive and Taxonomic Implications.” *Plant Biosystems* 153(5):710–19. <https://doi.org/10.1080/11263504.2018.1549601>
- Lorenz, K., And R. Lal. 2016. “Environmental Impact of Organic Agriculture.” Pp. 99–152 In *Advances in Agronomy. Vol. 139. Academic Press Inc.* <https://doi.org/10.1016/BS.AGRON.2016.05.001>
- Malhi, Gurdeep Singh, Manpreet Kaur, And Prashant Kaushik. 2021. “Impact of Climate Change on Agriculture and Its Mitigation Strategies: A Review.” *Sustainability (Switzerland)* 13(3), 1–21. <https://doi.org/10.3390/SU13031310>
- Martens, Joanne R. Thiessen, And Martin H. Entz. 2011. Integrating Green Manure and Grazing Systems: A Review. *Canadian Journal of Plant Science* 91(5), 811–24. <https://doi.org/10.4141/CJPS2010-035>
- Martínez-Alcántara, Belén, Martínez-Cuenca M.R., Bermejo A., Legaz F., Quiñones A. 2016. Liquid Organic Fertilisers for Sustainable Agriculture: Nutrient Uptake of Organic Versus Mineral Fertilisers in Citrus Trees. *Plos One* 11(10), e0161619. <https://doi.org/10.1371/JOURNAL.PONE.0161619>

- Marzouk, S.H., Semoka J.M., Amuri N.A., Tindwa H.J. 2024. Rice Straw Incorporation and Azolla Application Improves Agronomic Nitrogen-Use-Efficiency and Rice Grain Yields In Paddy Fields. *Frontiers In Soil Science* 4, 1378065. <https://doi.org/10.3389/FSOIL.2024.1378065>
- Marzouk, Said H., Hamis J. Tindwa, Nyambilila A. Amuri, And Johnson M. Semoka. 2023. “An Overview of Underutilized Benefits Derived from Azolla as A Promising Biofertilizer in Lowland Rice Production.” *Heliyon* 9(1), e12945. <https://doi.org/10.1016/J.HELİYON.2023.E12945>
- Mazid, Mohd, And Taqi Ahmed Khan. 2014. Future Of Bio-Fertilisers in Indian Agriculture: An Overview. Vol. 3. [Www.Sciencetarget.Com](http://www.Sciencetarget.Com).
- Meemken, Eva-Marie, And Matin Qaim. 2018. “Organic Agriculture, Food Security, And The Environment.” <https://doi.org/10.1146/ANNUREV-RESOURCE-100517-023252>
- Mosha, Sebastian S. 2018. “A Review on Significance of Azolla Meal as A Protein Plant Source In Finfish Culture.” *Journal Of Aquaculture Research & Development* 09(07). <https://doi.org/10.4172/2155-9546.1000544>
- Mukherjee, K., Konar A., Ghosh P. 2022. “Organic Farming In India: A Brief Review.” *International Journal of Research in Agronomy* 5(2), 113–18. <https://doi.org/10.33545/2618060X.2022.V5.I2B.120>
- Muktamar, Z., S. Sudjatmiko, F. Fahrurrozi, N. Setowati, And M. Chozin. 2017. “Soil Chemical Improvement Under Application of Liquid Organic Fertilizer In Closed Agriculture System.” *International Journal of Agricultural Technology* 13(2), 1715–27.
- Mwangi, Obadiah, Hottensiah Wambui, And Monicah Mucheru-Muna. 2024. “Influence Of Nutrient Management and Crop Rotation on Soil Weed Seedbank in Tharaka Nithi County.” *J. Mater. Environ. Sci* 2024(6), 821. [Http://Www.Jmaterenvironsci.Com](http://Www.Jmaterenvironsci.Com).
- Ostadi, Ali, Javanmard A., Machiani M.A., Morshedloo M.R., Nouraein M., Rasouli F., Maggi F. 2020. “Effect of Different Fertilizer Sources and Harvesting Time on The Growth Characteristics, Nutrient Uptakes, Essential Oil Productivity and Composition of Mentha X Piperita L.” *Industrial Crops and Products* 148. <https://doi.org/10.1016/J.INDCROP.2020.112290>
- Pampana, Silvia, Liaqat Shah, Mir Chakar Khan Rind University, Pakistan Fabio Orlandi, Muhammad Habib-Ur-Rahman Mhabibur, Hesham F. Alharby, Ayman El Sabagh, El A. Sabagh, Fpls Copyright, El Sabagh, Muhammad Habib-Ur-Rahman, Ashfaq Ahmad, Ahsan Raza, Muhammad Usama Hasnain, Yahya M. Alzahrani, Atif A. Bamagoos, Khalid Rehman Hakeem, Saeed Ahmad, Wajid Nasim, Shafaqat Ali, And Fatma Mansour. N.D. Open Access Edited By Impact Of Climate Change On Agricultural Production; Issues, Challenges, And Opportunities In Asia. Impact Of Climate Change On Agricultural Production: Issues, Challenges, And Opportunities In Asia. <https://Cdiac.Ess-Dive.Lbl.Gov/Home.Html>;
- Peigné, Joséphine, Marion Casagrande, Vincent Payet, Christophe David, F. Xavier Sans, José M. Blanco-Moreno, Julia Cooper, Kate Gascoyne, Daniele Antichi, Paolo Bàrberi, Federica Bigongiali, Andreas Surböck, Andreas Kranzler, Annelies Beeckman, Koen Willekens, Anne Luik, Darja Matt, Meike Grosse, Juergen Heß, Maurice Clerc, Hansueli Dierauer, Paul Mäder. 2016. “How Organic Farmers Practice Conservation Agriculture In Europe.” *Renewable Agriculture and Food Systems* 31(1), 72–85. <https://doi.org/10.1017/S1742170514000477>
- Piotrowska-Długosz, Anna, Edward Wilczewski. 2020. “Influence of Field Pea (Pisum Sativum L.) As Catch Crop Cultivated for Green Manure on Soil Phosphorus And P-Cycling Enzyme Activity.” *Archives of Agronomy and Soil Science*, 66(11), 1570–82. <https://doi.org/10.1080/03650340.2020.1715950>
- Prakash Aryal, Jeetendra, Tek Bahadur Sapkota, Timothy J. Krupnik, Dil Bahadur Rahut, Mangi Lal Jat, And Clare M. Stirling. N.D. “Factors Affecting Farmers’ Use of Organic and Inorganic Fertilizers In South Asia.” <https://doi.org/10.1007/S11356-021-13975-7>
- Rahman, K. M. Atikur, And Dunfu Zhang. 2018. “Effects of Fertilizer Broadcasting on the Excessive Use Of Inorganic Fertilizers And Environmental Sustainability.” *Sustainability (Switzerland)* 10(3), 759. <https://doi.org/10.3390/SU10030759>
- Rahmann, G., Mohammad Reza Ardakani, Paolo Bàrberi, Herwart Boehm, Stefano Canali, Mahesh Chander,

- Wahyudi David, Lucas Dengel, Jan Willem Erisman, Ana C. Galvis-Martinez, Ulrich Hamm, Johannes Kahl, Ulrich Köpke, Stefan Kühne, S. B. Lee, Løes A.K., Moos J.H., Neuhofer D., Nuutila J.T., Olowe V., Oppermann R., Rembialkowska E., Riddle J., Rasmussen I.A., Shade J., Sohn S.M., Tadesse M., Tashi S., Thatcher A., Uddin N., Peter Von Fragstein Und Niemsdorff, Wibe A., Wivstad M., Wenliang W., Zanoli R. 2017. "Organic Agriculture 3.0 Is Innovation with Research." *Organic Agriculture* 7(3), 169–97. <https://doi.org/10.1007/s13165-016-0171-5>
- Rajvir, Singh, And Shahi Sudhir Kumar. 2013. Role Of Bio-Fertilizer In Organic Agriculture: A Review. Vol. 2. [Www.Isca.In](http://www.isca.in).
- Randive, Kirtikumar, Tejashree Raut, And Sanjeevani Jawadand. 2021. "An Overview of the Global Fertilizer Trends and India's Position In 2020." *Mineral Economics* 34(3), 371–84. <https://doi.org/10.1007/S13563-020-00246-Z>
- Roba, Tesfaye Burju. 2018. "Review On: The Effect of Mixing Organic and Inorganic Fertilizer on Productivity and Soil Fertility." *Oalib* 05(06):1–11. <https://doi.org/10.4236/OALIB.1104618>
- Sabbahi R., Hock V., Azzaoui K., Saoiabi S., Hammouti B. (2022). A global perspective of entomopathogens as microbial biocontrol agents of insect pests, *Journal of Agriculture and Food Research* 10, 100376, <https://doi.org/10.1016/j.jafr.2022.100376>
- Said, D. S., T. Chrismadha, Y. Mardiati, And N. Mayasari. 2023. "Nutritional Content and Growth Ability of Aquatic Plant Azolla Pinnata on Wastewater of Catfish." In Iop Conference Series: Earth and Environmental Science. Vol. 1260. *Institute of Physics*. <https://doi.org/10.1088/1755-1315/1260/1/012031>
- Santos, João A., Fraga H., Malheiro A. C., Moutinho-Pereira J., Dinis L.T., Correia C., Moriondo M., Leolini L., Dibari C., Costafreda-Aumedes S., Kartschall T., Menz C., Molitor D., Junk J., Beyer M., Schultz H.R. 2020. "A Review of the Potential Climate Change Impacts and Adaptation Options For European Viticulture." *Applied Sciences*, 10(9). <https://doi.org/10.3390/APP10093092>
- Sapna, Lingaraju, And J. Mater. 2022. "Azolla: a Organic Feed for Fish Farming-Review." *J. Mater. Environ. Sci* 2022(3):3. [Http://Www.Jmaterenvirosci.Com](http://www.jmaterenvirosci.com).
- Seleiman, Mahmoud F., Omnia M. Elshayb, Abdelwahed M. Nada, Sara A. El-Leithy, Lina Baz, Bushra A. Alhammad, and Ayman H. A. Mahdi. 2022. "Azolla Compost as an Approach for Enhancing Growth, Productivity and Nutrient Uptake of Oryza Sativa L." *Agronomy* 12(2). <https://doi.org/10.3390/AGRONOMY12020416>
- Serdeczny, O., Sophie A., Florent B., Coumou D., Robinson A., Hare W., *et al.* 2017. Climate Change Impacts In Sub-Saharan Africa: From Physical Changes to Their Social Repercussions. *Regional Environmental Change* 17(6), 1585–1600. <https://doi.org/10.1007/S10113-015-0910-2>
- Shahid, Mohammad, Sushmita Munda, Rubina Khanam, Dibyendu Chatterjee, Upendra Kumar, Bs Satapathy, S. Mohanty, D. Bhaduri, R. Tripathi, Pk Nayak, And Ak Nayak. 2021. "Climate Resilient Rice Production System: Natural Resources Management Approach." *Oryza-An International Journal on Rice* 58(Special):143–67. <https://doi.org/10.35709/ORY.2021.58.SPL.6>
- Shaji, Hitha, Vinaya Chandran, And Linu Mathew. 2021. "Organic Fertilizers as a Route to Controlled Release of Nutrients." Pp. 231–45 In Controlled Release Fertilizers for Sustainable Agriculture. *Elsevier*. <https://doi.org/10.1016/B978-0-12-819555-0.00012-1>
- Shamsuddoha, A. T. M., Md Nazmul Haque. 2017. "Effect of Organic and Inorganic Fertilizer on The Growth and Yield of Rice (Oryza Sativa L.)." 5(Ii), 677–80. <https://doi.org/10.7537/MARSNSJ14021607>
- Sharma, Ameeta. 2017. "A Review on the Effect of Organic and Chemical Fertilizers On Plants." *International Journal for Research in Applied Science and Engineering Technology* V(Ii), 677–80. <https://doi.org/10.22214/IJRASET.2017.2103>
- Da Silva, Jesus M.E., Joy Mathe L.O., Van Rooyen I.L., Brink H.G., Nicol W. 2022. Optimal Growth Conditions for Azolla Pinnata R. Brown: Impacts of Light Intensity, Nitrogen Addition, Ph Control, and Humidity. *Plants* 11(8), 1048. <https://doi.org/10.3390/PLANTS11081048>
- Tao, Jiemeng, Liu X., Liang Y., Niu J., Xiao Y., Gu Y., Ma L., Meng D., Zhang Y., Huang W., Peng D., Yin

- H. 2017. Maize Growth Responses to Soil Microbes and Soil Properties After Fertilization with Different Green Manures. *Applied Microbiology and Biotechnology* 101(3), 1289–99. <https://doi.org/10.1007/S00253-016-7938-1>
- Thapa, Parbati, And Kabita Poudel. 2021. “Azolla: Potential Biofertilizer For Increasing Rice Productivity, And Government Policy for Implementation.” *Journal Of Wastes and Biomass Management* 3(2), 62–68. <https://doi.org/10.26480/JWBM.02.2021.62.68>
- Thomas, Cathy L., Gifty E. Acquah, Andrew P. Whitmore, Steve P. Mcgrath, And Stephan M. Haefele. 2019. “The Effect of Different Organic Fertilizers on Yield and Soil and Crop Nutrient Concentrations.” *Agronomy* 9(12), 776. <https://doi.org/10.3390/AGRONOMY9120776>
- Tripathi, A., Ashok K. M. 2017. Knowledge and Passive Adaptation to Climate Change: An Example from Indian Farmers, *Climate Risk Management* 16, 195–207. doi.org/10.1016/J.CRM.2016.11.002
- Utomo, Ristiano, Cuk Tri Noviandi, Nafiatul Umami, And Adhitya Permadi. 2019. “Effect of Composted Animal Manure as Fertiliser on Productivity of Azolla Pinnata Grown in Earthen Ponds.” *Online Journal of Biological Sciences* 19(4), 232–36. <https://doi.org/10.3844/OJBSCI.2019.232.236>
- Wang, Yan, Yuchun Zhu, Shuoxin Zhang, And Yongqiang Wang. 2018. “What Could Promote Farmers to Replace Chemical Fertilizers with Organic Fertilizers?” *Journal of Cleaner Production* 199, 882–90. <https://doi.org/10.1016/J.JCLEPRO.2018.07.222>
- Yadav, R. K., G. Abraham, Y. V. Singh, And P. K. Singh. 2014. “Advancements in the Utilization of Azolla-Anabaena System in Relation to Sustainable Agricultural Practices.” *Proceedings of the Indian National Science Academy*, 80(2), 301–16. <https://doi.org/10.16943/PTINSA/2014/V80I2/55140>
- Zhang, Xiaoxia, Ruijie Zhang, Jusheng Gao, Xiucheng Wang, Fenliang Fan, Xiaotong Ma, Huaqun Yin, Caiwen Zhang, Kai Feng, And Ye Deng. 2017. “Thirty-One Years Of Rice-Rice-Green Manure Rotations Shape the Rhizosphere Microbial Community and Enrich Beneficial Bacteria.” *Soil Biology and Biochemistry* 104, 208–17. <https://doi.org/10.1016/J.SOILBIO.2016.10.023>
- Zhao, Jun, Tian Ni, Jing Li, Qiang Lu, Zhiying Fang, Huang Q., Zhang R., Rong L., Biao S., Qirong S. 2016. Effects of Organic-Inorganic Compound Fertilizer with Reduced Chemical Fertilizer Application on Crop Yields, Soil Biological Activity and Bacterial Community Structure in a Rice-Wheat Cropping System. *Applied Soil Ecology* 99, 1–12. <https://doi.org/10.1016/J.APSOIL.2015.11.006>

(2026) ; <http://www.jmaterenvirosci.com>