How Sustainable Agriculture Can Reduce Environmental Damage and Yield Economic Benefits: A perspective – Part 2

Ramanatha Rao V, CL Laxmipathi Gowda, and SV Raghuram Shetty

Introduction

As we said noted in the Outline at the beginning of these 3-part series (see Part 1), we will elaborate on issues that affect SA at MA at the global level, and suggest the use of integrative models, such as limiting of external inputs, payment for ecosystem services, value-chain diversification, and blended finance, to ensure that environmental damage is minimised, while food security is assured, along with increasing returns for farmers by practising SA. Such models would include payment for ecosystem services, value-chain diversification, and blended finance.

This Part 2 is divided into three Sections (Nos. 3, 4, and 5) while Part 1 consisted of two Sections Nos. 1 and 2). Now, in Section 3, beginning here, we look at the gains and risks involved in following the two farming approaches, SA and MA. In Section 4, we consider factors that might present difficulties in implementing SA, in places where MA is already entrenched. In Section 5, we provide concluding remarks for Part 2, along with some suggestions or recommendations for the successful implementation of SA.

Section 3. Gains and Risks in Farming Approaches

The positive outcomes from switching to SA will not be evident immediately, as they will need time to manifest themselves. While switching to a newly developed technology may show immediate benefits, the chances of causing long-lasting damage thereby to the soil and environment are also greater. Improvement in the community life of farmers and others can only be provided by the switch to SA.

We next enumerate the benefits and losses from the two approaches, which are evidence-based and not anecdotal. To help balance the major goals of food and nutritional security, environmental health, and improving the livelihoods of those living off agriculture, we suggest combining measures like paying for environmental services, making food supply chains more varied, and using a mix of public and private funding or blended finance.

3.1 Gains from Sustainable Agriculture

The main gains from practising SA include improvement of nature's health; reduced dependence on external inputs, especially of chemicals; improved nutritional benefits for people; and stronger community life, fostering trust, reciprocity, and collective action within communities.

3.1.1 Restoring nature's health: Natural environments, which have been damaged or degraded, need help to recover. One does so by measures to bring back nature's essential services, such as providing clean water, fertile soil, and safeguarding and sustainably using biodiversity. Included are activities such as afforestation, bringing wetlands back to life, and managing harmful invasive species. When done successfully, such restoration helps the environment to better withstand climate change, safeguards various species, and secures the natural resources that are essential for humans and other living beings. It is an important aspect of global conservation and sustainability efforts.

3.1.2 Less reliance on external inputs: Low-input farming systems minimize the need for external resources, drastically reducing the use of synthetic fertilizers, chemical pesticides, and imported livestock feed. Key examples are reducing the use of chemical fertilizers and pesticides, and of excessive tillage and watering. Adopting nature-friendly farming methods, such as minimum tillage, planting diverse crops in rotation, mixed cropping, and using natural soil improvements, also helps, as they boost soil health, reduce water and air pollution, and minimize crop loss from pests. These practices result in lower running costs and costs of production, as well as protection from price fluctuations, leading to more sustainable use of local resources.

3.1.3 Improved nutrition for all: Enhancing global nutrition requires increasing both the availability and quality of nutrient-dense food, while also ensuring all communities have access to balanced, healthy diets. Nutrition goes beyond having enough calories, and includes access to a wide range of vitamins, minerals, and proteins from diverse foods. Such initiatives often promote growing and consuming crops packed with nutrients, especially fruits, vegetables, and beans/legumes, which will lead to healthy eating in general. Improved nutrition is crucial for public health, helping with mental development, strengthening the body's immunity, and reducing illnesses linked to poor diets. There is increased information regarding imbalanced nutrition content in products grown using MA; therefore, dependence on organic or natural farming is gaining popularity because of the importance of having diversity in diets for wholesome nutrition.

3.1.4 Stronger community life: SA is not merely a set of agricultural practices; it is a significant driver of social capital (**Humans,** the primary element in any production system), fostering trust, reciprocity, and collective action within communities. Local food systems, which shorten the supply chain and physically and socially reunite producers and customers, are the foundation of SA. This broad concept includes all the social, financial, environmental, and cultural conditions needed for individuals and groups to thrive where they live. It is measured by things like how safe people feel, their health status, how stable the economy is, how well people get along, and their access to green spaces. It also helps reduce migration to cities. Efforts to improve community well-being often involve letting local people have a say in decisions, fair sharing of resources, and building stronger social connections. Communities with a keen sense of well-being are more able to recover from disasters and other challenges, are more productive, and have happier residents, leading to a higher quality of life overall.

By utilizing such environment-friendly practices, SA builds organic matter and preserves the complex microbial ecosystems within the soil; it thus creates a selfsustaining cycle that improves water retention and ensures the land remains productive for future generations.

3.2 Risks of Sustainable Agriculture

It is true that SA is not risk-free, and one must understand the nature and extent of risk(s) before it is adopted on a large scale. Such risks could be (1) high initial costs and the risk of transition; (2) more complex management and higher labour needs: (3) possible lower yields at the initial stage/s; and (4) challenges associated with markets, prices, and infrastructure. As the soil microbiome recovers when synthetic fertilizers are phased out, crop yields often dip temporarily. Both the plant and the soil need to time to adjust to a new, non-chemical environment, and so crop yields might be lower in the beginning before they pick up over the years. There are also challenges associated with markets, prices, and infrastructure. These are explained next for a better understanding of the issues and how to address them.

3.2.1 High initial costs and the risk of transition: Moving from MA to sustainable methods often requires a big initial investment. Some of the costs could include soil regeneration through organic matter, requiring investment in cover crop seeds, compost, etc., implementing precision irrigation or rainwater harvesting systems, and buying new no-tillage seed drills. For organic certification, farmers must follow a set of agreed practices, and certification could also involve some time and expenses.

3.2.2 More complex management and higher labour needs: Practicing sustainable farming requires specialized knowledge, calling for a detailed, site-specific understanding of the natural environment, soil, and how to manage pests without chemicals (Integrated Pest Management or IPM), composting, and diverse crop rotations. All these often require regular personal monitoring and more labour than the "spray-and-and forget" approach. Sustainable tasks, such as controlling weeds by hand or machine (instead of using spray), carefully planning crop rotations, and managing nutrients on the farm (composting/manure), need more manual work than conventional farming, thus increasing the cost of running the farm. However, most smallholder and middle level farmers are aware of these practices and adopt at least a few. The large farms may still have a problem in trying to practice these measures.

3.2.3 Possible lower yields at the initial stage/s: As the soil microbiome recovers when synthetic fertilizers are phased out, crop yields often dip temporarily. Both the plant and the soil need to time to adjust to a new, non-chemical environment, and so crop yields might be lower in the beginning. Sustainable farms eventually achieve harvests that match conventional yields, but it can be hard to scale these successes up to the massive production levels of industrial farming. That, in turn, raises concerns about being able to feed a growing global population.

3.2.4 Challenges associated with markets, prices, and infrastructure: The extra labour, lower initial yields, and specialized handling needed for SA can result in higher prices of the produce for the customer. Smallholder farmers can struggle to get their products into the usual, large-scale production and supply chains. Getting and retaining organic certification can also be a major obstacle, especially for small farmers.

Thus, the most significant disadvantage of transitioning from MA to SA is the initial decline in crop yields and the economic risk.

3.3 Gains of Modern Agriculture (MA)

Modern agriculture transforms the sector from subsistence farming into a highly productive, resilient, and technology-driven industry. The major gains for farmers include (1) rapid generation of capital; (2) technological advancement; resulting in (3) higher productivity and financially security in the short term.

3.3.1 Quick capital generation: Modern farming uses crop varieties that respond well to chemical fertilizers to get high yields. Higher yields enable easy sale of large amounts of produce of staple crops, bringing in quick gross returns on the investment, despite the high input costs. The faster money flow helps cover immediate business costs and allows MA farmers to reinvest capital quickly for the next growing cycle.

3.3.2 Technological advancement: Most research efforts, both currently and in the recent past, have been focused on increasing crop yield per unit area. Modern farming methods drive the adoption of large-scale machinery and advanced precision technology (though this technology is also important in SA). These modern tools, such as automated tractors and sprayers, increase the efficiency of labour and allow farmers to cultivate large areas with fewer workers, thus reducing recurring costs of labour, as well as reduced dependence on labour availability.

3.3.3 Higher productivity and financial security: The reliable, large harvests resulting from dependable pest control provide farmers with food and financial security. By minimizing the loss of crops to diseases and insect pests, etc., modern farming practices ensure a reliable income stream, reducing the immediate risk of a harvest failure and securing a farmer’s ability to cover living expenses and repay short-term loans.

Thus, MA is designed for maximum efficiency and predictability. By utilizing synthetic inputs, genetically optimized seeds, and heavy mechanization, it bypasses many of the natural limitations within which SA must work.

3.4. Risks of Modern Agriculture (MA)

While MA does have the advantages we just listed, most chemical inputs tend to (1) damage the environment (pollution, soil degradation); (2) result in largescale clearing of forests; (3) increase cost, resulting financial instability; (4) increase social and health problems; and (5) cause resource depletion, resulting from excessive use of water, fertilisers, and pesticides.

3.4.1 Damage to the environment: Injudicious use of chemical fertilizers causes water pollution and creates "dead zones" in waterways. Non-judicious use of pesticides harms beneficial insects and other creatures, reduces biodiversity, and leads to the creation of drug-resistant "super-pests." Ploughing the soil repeatedly results in severe soil erosion and the loss of vital organic material. Soil health is also affected, as most of the applied chemicals kill beneficial microorganisms and disrupt the natural nutrient cycling. Harmful chemicals build up in the food chain, hurting animals, plants, and people.

3.4.2 Loss of forested land: Cutting down forests for farming can harm global food production, because forests help control rainfall through their role in recycling moisture into the atmosphere. Large forests such as the Amazon, Congo, and Indonesian forests act as "pumps," helping to maintain regular rain patterns even at far distances. Destroying these forests can reduce rainfall in important farming areas around the world. Thus, protecting tropical forests is essential for keeping the climate stable and ensuring reliable food production.

3.4.3 Economic instability: As a result of the risks we have listed, the economic advantage gained through MA practices may be lost, owing to degraded soils affecting financial security in the long term. Heavy reliance on expensive, non-locally sourced materials (fertilizers, chemicals, seeds, etc.) increases the farmers' debt and their financial risk. As the soil degrades and water becomes scarce (for most chemicals and improved varieties to work, greater amounts of water are needed) and as the biotic and abiotic stresses increase owing to such changes in the environment, the net profit becomes smaller. This dependence on global supply chains makes farms highly vulnerable to sudden price spikes and market instability, which undermines their ability to be financially secure over the long term.

3.4.4 Social and health problems: MA can also result in disruption of the social fabric of a community. Small-scale farmers may lose their land or livelihoods, owing to the dominance of large agribusinesses, resulting in displacement or economic hardship. Over the years, traditional farming knowledge and cultural practices may be lost. Inequality, which is already considerable in many countries, may increase as benefits often go to larger, wealthier producers. Also, exposure to chemicals from pesticides poses a health hazard for farm workers and the people who live around farms, resulting in illness, such as respiratory issues, skin disorders, and even cancer. Consumption of food with chemical residues may also impact long-term health.

3.4.5 Resource depletion: Intensive irrigation for high-yielding crops leads to the unsustainable depletion of finite groundwater (aquifers). The energy-intensive production of synthetic nitrogen fertilizers relies heavily on fossil fuels, making the entire system a significant contributor to greenhouse gas emissions. The resulting resource depletion poses a major challenge for the future of agriculture, threatening food security and requiring significant changes in how we farm and manage natural resources. Is that the sort of legacy we want to leave for the future generations?

To sum up, the practice of MA over some years results in reduced productivity, increased input costs (water, fertilizers, and fuel), as well as considerable environmental degradation (loss of soil fertility, water shortage, and biodiversity) making land less suitable for agriculture. See Table 1 for a quick comparison of MA vs SA.

Table 1. Agricultural evolution: A comparison

Feature	Modern Agriculture (MA)	Sustainable Agriculture (SA)
Primary Goal	Maximum yield per unit area	Stable yields, with long-term ecosystem resilience
Input Source	External/Synthetic (fossil fuel/synthetic based)	Internal/Biological (diverse crops, compost, green manure, N-fixation)
Risk Profile	High (vulnerability to climate/market volatility)	Low (diversified income/climate hardy)
Soil Health	Declining (less fertile, erosion/salinity)	Improving (improved soils with appropriate microbiome, increased organic matter, carbon sequestration)

Although researchers and policymakers have been talking about SA for some few decades now, planned experiments of SA are of more recent origin. Based on a few studies, which were reviewed while developing this Perspective paper, some of the evidence-based benefits and risks of CA and SA are shown in Table 2.

Table 2. Benefits and risks of MA, the transitional phase, and SA

Metric	Modern Agriculture	Period of Transition to Sustainable Agriculture	Sustainable Agriculture (Established)
Input Cost	High (Synthetic Chemicals, Energy)	Variable/High (Initial capital/training)	Low (Displaced by Ecosystem Services)
Short-Term Profitability (Years 1-3)	Stable (Supported by Policy/Subsidies)	Loss of Profitability	Increasing/Stable
Long-Term Profit Potential	Moderate/Stable	N/A	High
System Resilience	Low	Building up	High
Duration of Transition	N/A	3–5 Years	N/A

Section 4. Difficulties in implementing SA

There are various economic, social, technical, and environmental factors which can make the switchover to SA difficult for both farmers and policymakers. These factors include (1) feeding a growing population; (2) shifting environmental harm to other countries; (3) consumer demand and crop wastage for farmers; (4) unfair access to resources; and (5) dealing with detractors; and (6) policy issues.

4.1 Feeding a growing population: With the increasing world population, farming is always under pressure to produce more and diverse foods. The need for greater output and diversity of food may conflict with sustainable farming methods, which produce less food per unit area (at least for the first few years) and, therefore, require more land. Nevertheless, the evidence supporting the capacity of SA to feed the increasing population is strong and growing, though it is contextual and not without complexity. That complexity needs to be the focus of ongoing and future studies.

4.2 Shifting environmental harm to other countries: If wealthy nations pass stricter environmental protection laws at home without considering the effects on global trade, they run the risk of simply pushing environmental damage elsewhere. Harmful practices, such as clearing forests and using substantial amounts of chemical fertilizers and pesticides, may simply move such damage to regions that have fewer or less rigid environmental rules.

4.3 Consumer demand and crop wastage for farmers: Most often, people who buy food and the people who grow it do not know each other. Consumers buy different kinds of fruits and vegetables, healthy cereals, and meat. Farmers need to be aware of these changing consumer demands, which will provide opportunities to grow the different kinds of crops needed by the consumers. Lack of such knowledge can result in a lot of wastage in terms of unwanted products, which amount to wasted produce and a postharvest loss for farmers. Such variation in consumer preferences and the crop produced—and wasted—can be, for example, in uniformity of shape and size of tubers (or fruits or vegetables).

4.4 Unfair access to resources: In rural communities, different types of farmers (smallholder/large/ethnic group/tenant) have unequal access to resources. Unfair access to resources creates a big gap between small-scale or marginalised farmers, on the one hand, and wealthy farmers, on the other, as the former do not have the money or land security to invest in long-term sustainable practices. Wealthy farmers can afford high-tech precision tools and organic certifications, but farmers who do not have adequate resources often have to use cheaper, chemical-heavy methods that prioritise short-term survival and yields. Also, these farmers cannot switch from traditional, soil-depleting systems because they do not have access to specialised technical training or seeds that can survive in different climates. In the end, this inequality keeps smallholder producers stuck in a cycle of poverty and environmental damage, which makes it almost impossible to make a big change toward global sustainability.

4.5 Dealing with detractors: There are a significant number of detractors of SA. For example, some argue that the real-world consequences of achieving the "organic transformation" can be seen in the recent Sri Lankan crisis in 2022, when a ban on chemical fertilizers resulted in falling crop yields, skyrocketing food prices, and a political crisis. While climate change presents challenges to our food systems, the answer does not lie in rejecting modern agriculture, they say. They assert that we should rely on technological breakthroughs and the adoption of existing technologies to improve food security.

4.6 Policy changes and global programmes: Many challenges for the transition to SA have been listed in world literature, but those challenges can be solved with careful planning. One can also note that many of the dissenting voices come from nations with industrial agriculture, manufacturers of modern agricultural chemicals, and climate change deniers. At present, the distribution of farm sizes is very uneven, and it adds to the constraints in the transition to sustainable agriculture (Table 3).

Table 3. Constraints for transition to SA in different regions, based on the predominant farming type.

Region	Predominant Farm Type	Key Constraint
Americas/Australia	Large-scale Industrial	Infrastructural Lock-in
South Asia/Africa	Smallholder/Subsistence	Resource and Credit Access
Europe	Mixed/Highly Subsidized	Policy Misalignment

Smallholder farms are more common in South Asia and Africa, but there are also considerable numbers in other countries. These smallholder farms are especially important for the livelihoods of people in the area, and they need long-term, stable support to do well.

Climate change and worries about global food security are already having an impact on agricultural production. For instance, the predicted drop in wheat production (from global warming) calls for quick, creative responses. These include adaptation subsidies that are administered locally, simpler administrative processes, and stronger ties between foreign development banks and agricultural ministries. Public financial support is still especially important, especially for family farming, to make sure that investments get to the most vulnerable farmers who are on the front lines of food security.

To achieve SA on a global scale, we need to work together to balance economic, social, and environmental goals. To build resilience, we need to use knowledge, a fairer sharing of resources, and new technologies. Many people are hopeful that new technologies and targeted efforts may make our food systems safer, but we need the help of development economists and agricultural professionals. In the end, this change is not merely an environmental choice; it is also necessary because resources are running out and demand is rising around the world.

Section 5. Conclusion and Recommendations

Available data show that SA offers a better, long-term financial and ecological path, compared to the conventional high-input farming model, promising significant and sustained economic benefits and enhanced systemic resilience. Despite this clear advantage, a full-scale transition is currently stalled by deep systemic inertia, driven by existing government policies, financial structures, and market value chains that favour the status quo. Since no single solution fits all areas, we must abandon the ineffective practice of treating sustainable agriculture development as a mere "co-benefit" of climate and biodiversity efforts. The interwoven problems of quality of life, degradation of nature, and climate change demand complementary, location-specific strategies. Smarter agricultural and land-use policies are essential to address the future shifts in demand, technology, and environment, and to protect our natural world for future generations. The difficulty in scaling this necessary change hinges on three interconnected structural constraints, demanding that we prioritize solutions that secure public-private support and benefit both people and nature. These constraints are discussed next.

5.1 The difficulty in scaling-up hinges on three interconnected structural constraints:

The three major constraints, (1) financial uncertainty, (2) enabling policies, and (3) infrastructural issues, are explained hereunder.

5.1.1 Financial uncertainty: The significant short-term profitability loss in SA creates an economic barrier that conventional lending and insurance systems are incapable of absorbing. There appear to be no financial and other subsidies for growing diverse crops in much of the world. There is a reason for this: India and China subsidize diverse cropping, and they lead the world in producing an incredibly diverse array of local food crops, rather than defaulting entirely to monoculture. Japan, Ethiopia, Peru, and some European countries also subsidize diverse cropping systems.

5.1.2 Policy misalignment: By rewarding MA with its heavy reliance on chemical pesticides and fertilisers, current agricultural policies and government subsidies create an unfair playing field. These financial safety nets shield MA's earnings while neglecting the "hidden" costs of environmental degradation, such as soil health, water pollution, etc. MA’s products continue to be artificially cheap because the public, not the producers, is responsible for the ecological imbalance. In contrast, sustainable farmers are required to bear the entire cost of land stewardship, which raises the perceived value of their goods. In the end, such an economic structure keeps the sector in a vicious cycle, where eco-friendly innovation is not rewarded but rather a financial risk.

5.1.3 Infrastructural lock-in: Our current food system is designed to handle just a few mass-produced staple food crops, which makes it a rigid system that values quantity over diversity. Mechanical harvesting, processing plants, and shipping networks are designed for these huge monocultures, but they cannot handle a diversity of crops, which are smaller in area and quantity of production. This technical mismatch keeps the agricultural industry stuck in a cycle where ecological health is sacrificed for logistical efficiency.

5.2 Suggestions for Successful Implementation of SA

To overcome the difficulties/constraints we already noted, there is a need for supportive policies, and for financial and logistical support to make the transition from MA to SA smoother and more attractive to farmers. We will now offer a few suggestions for future work on SA globally (many of these apply to the Indian scenario as well, as we will show in **Part 3**)

5.2.1 Integrated policy and subsidy reform: There is a clear need to move away from "one-size-fits-all" methods, and to adopt strategies that are specific to each location, and that address biodiversity and climate as linked goals. Governments need to change the criteria for grants and subsidies, so that they do not support practices that hurt the environment and instead shift to those that show good ecological results. This means giving smallholder farmers more power and a "from-bottom-up" way to get involved.

5.2.2 Infrastructure and financial mobilisation: We need to use regenerative crop warranties and specialised lending to get public and private money to help pay for a transition period of 3 to 5 years. Funding needs to be decentralised and focused on local processing capabilities, for it to break the current pattern of monoculture infrastructure lock-in and let a diversity of crops into the market.

5.2.3 Precision R&D and efficient use of resources: We need to put money into advanced modelling and climate-resilient crop varieties, including gene-edited varieties. Using modern tools, such as sensors and data analysis, to provide water and nutrients where they are needed, is also crucial. Five-year plans and independent expert reviews must back up this "nature-first" R&D approach for sustained funding.

5.2.4 Farming practices that help the environment: As farmers change farming practices—combining forestry, minimal disturbance, and plant variety—there are greater opportunities to build a resilient, biodiverse ecosystem, which improves long-term soil health and profitability. Such changes prevent soil degradation, cut input costs, and ensure multiple income streams. Farmers thus need to change current farmland practices to accommodate agroforestry, conservation tillage/minimum tillage/no till, integrated pest management, and cultivation of diverse crops. These practices make the soil healthier and the ecosystem more resilient, which means that crop productivity will last longer.

5.2.5 Capacity building and participatory research: We need to fund large-scale upskilling to give farmers the ecological knowledge they need to use regenerative systems. Encouraging participatory research, where scientists and farmers work together to create new knowledge, will go a long way. Modern tools can then be used with traditional practices, adapted to the local conditions.

Summing up

To sum up, environmental stewardship and financial resilience need to work together in a planned way for SA to be effective. We can protect profits and restore the land for future generations by using flexible policies, new technology, and fair market rules. In the end, all this can lead to long-term food security by balancing people, the planet, and profit through flexible research and strong partnerships.

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