How Sustainable Agriculture Can Reduce Environmental Damage and Yield Economic Benefits: A perspective – Part 1

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Introduction

The world's agricultural landscape is at a very important point in its history. The Food and Agriculture Organization (FAO) said in 2018 that it is very important to make farming practices more environmentally friendly, while also meeting the needs of the economy and society right away. Most who argue that sustainable farming does not help economic development tend to forget the economic costs of modern farming to farmers and the world at large. This paper, divided into three sections, examines Sustainable Agriculture (SA), not only as a theoretical concept, but as an essential means for global survival.

Traditional research has always put the priority on maximum food output, but the more recent shift to SA presents a more difficult problem: how to feed 10 billion people by 2050 without harming the ecosystems that make food production possible. To tackle this, our study looks at a few important pillars.
While recognising the vital contributions of modern agriculture (MA), we prioritise the production of food crops and the role of smallholder farmers in the developing countries. We argue for an economic balance and look at the essential conflict between attaining immediate financial gain and guaranteeing long-term ecological sustainability. We consider resilience vs. decline, i.e., we contend that to stop additional environmental deterioration, agriculture must be converted into a regenerative, climate-resilient force.

The planet's ability to support future generations ultimately depends on how quickly sustainable policies are put into place. We explain the precise steps needed to go from traditional farming practices to a truly sustainable agricultural future in this 3-part series. Parts 2 and 3 will follow in ensuing weeks.

The switchover to SA, which is more resilient than MA, requires bold, coordinated action. Such action includes government policies that reward taking care of nature, such as conservation farming and restorative agriculture (agroforestry, low input farming, etc.). There are some indications that change is already happening, and that the focus is slowly shifting toward adaptation measures, since mitigation is difficult to practice by farmers in most parts of the world.

Statement of Purpose

This paper, presented in 3 parts, aims to address the urgent need to promote SA as a key pathway to protect the environment, while also addressing immediate social and economic needs (the related policy issues were noted by FAO, the Food and Agriculture Organization, in 2018). Further, it seeks to elucidate how the speedy implementation of SA can benefit the world and future generations. While

conventional agricultural research has always had as its primary focus the highest possible food production, research on SA tries to figure out how to feed 10 billion people by 2050 without hurting the systems that food production primarily depends upon.

In the Sections that follow, we will explain what actions will be needed to make agriculture sustainable. In doing so, we focus primarily on food-crop production and smallholder farming in the developing world, while also acknowledging that commercial crops and livestock production also form a key component of SA. We need to consider both short-term profits and long-term sustainability. The choice is clear: either make farming a climate-resilient, regenerative force; or let it get worse, which will speed up the planet's environmental decline. SA is not just an option to consider; it is the most important requirement that will decide whether future generations get a planet that can feed and support itself.

Outline

As we said earlier, this paper is presented in in three parts. In **Part 1**, we argue that the purpose of promoting sustainable agriculture is to create a resilient food system that meets current demands and future needs, ensuring long-term food security and supporting farmers' incomes and development, without compromising on environmental well-being. We also consider in this part biophysical and socioecomic factors that are needed to promote SA, the trap of short-term economic gains of MA and focus on long-term gains from SA.

In **Part 2** we will elaborate on issues that affect SA and 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 (as noted by UNEP, the United Nations Environment Programme).

In **Part 3,** we will look at the status of implementation of SA vis a vis MA in India and offer some suggestions to those engaged in implementing it.

We will also provide a list of resource material for further reading at the end of **Part 3**.

Section 1. Sustainable Agriculture (SA) and its Components

In this Section, we draw a clear distinction between SA and modern agriculture (MA), such as the need to balance productivity with environmental protection, economic viability, and social well-being over the long term. SA focuses on conserving soil and water, reducing harmful inputs, supporting farmers' livelihoods, and building resilient food systems for present and future generations. **SA** uses practices that many farmers have been using for centuries. Techniques from MA, which prioritised the best return per unit of land, replaced such practices. Farmers have tended to use techniques to maintain healthy soils, and to use water and

manures appropriately. Farmers have mostly engaged in diverse agriculture to meet the demands of their households.

We elaborate briefly on the role of such practices in SA under two broad sub-categories: (1) biophysical factors; and (2) socioeconomic factors.

1.1 Biophysical Factors

Under biophysical factors, we need to consider (1) healthy soils, (2) smarter use of fertilizers, (3) wiser use of water, (4) agroforestry and related practices, and (5) renewable energy.

1.1.1 Healthy soils: Healthy, "living soils" are an important requirement of SA, as they enable adaptation to climate change, by maintaining or enhancing soil fertility. Planting cover crops (crops planted to cover the soil: the choice of crops may vary, depending on climate, soil type, and farming goals; however, legumes are preferred because of their N2 fixing ability and because shorter-duration crops can bring in additional income), minimum tillage, and adding organic matter (such as compost or farmyard manure) are all practices that help build up soil organic carbon.

Those methods make the soil healthy and more productive, by helping it hold more water, thus reducing erosion and improving the way nutrients move through the soil. Cover crops protect the soil surface, reduce soil erosion, and add plant material; in addition, shorter-duration crops can provide a cash benefit. Minimum tillage protects the soil's structure and the soil micro-biota. Organic matter adds carbon and nutrients to the soil, which helps it stay fertile for a longer time. Studies from around the world show that these practices can store a considerable quantity of organic carbon when they are adapted to fit the needs of the area. Keeping soils healthy is thus an important way to fight climate change and keep farms productive.

1.1.2 Smarter use of fertilisers: Smarter nutrient management is an effective way to lower greenhouse gas emissions from farms, without reducing the number of crops. Judicious use of fertiliser, at the right time and in the right place, can lower the amount of Nitrous oxide (N_2O) that is released into the atmosphere. Nitrous oxide is a major greenhouse gas linked to injudicious fertiliser use. Consider integrating its use with eco-friendly fertilisers (such as compost, green manure, etc.) that are low in carbon and composed of plant material. These manures are better for the environment and make supply chains more resilient.

Using slow-release fertilisers with better efficiency also helps crops get more nutrients and makes the soil and air less polluted. To keep greenhouse gas (GHG) emissions in check, it is important to apply fertiliser to the crop at the right time. Intergovernmental Panel on Climate Change (IPCC) says that better nutrient practices could cut GHG emissions by 10 to 50 percent (2022).

1.1.3 Wiser use of water: Studies have shown that judicious use of water helps not only in obtaining optimum yields but also in mitigating the impact of climate change. Among crops, rice—especially irrigated rice— is a key target for climate-smart agriculture practices, such as improved water management and the

breeding of low methane-emission varieties, to reduce its environmental impact. It has been shown, for example, that direct-seeded rice (DSR) and alternate wetting and drying can together lower methane emissions while still getting better yields. We need to consider the optimum use of water for other crops as well. Here are some ways that lead to stable yields with optimal water use:

- Using drip or sprinkler irrigation.
- Planting crops that can tolerate drought.
- Managing soil and crops (for example, mulching and conservation tillage).
- Using technologies for precise water management that include real-time crop data, soil moisture monitoring (including sensors and weather forecasts), and other AI tools.

Several researchers have shown that efficient use of water typically improves nitrogen-use efficiency (NUE), instead of producing carbon dioxide and/or nitrous oxide. If water is applied precisely (e.g., via Fertigation), the plants absorb more fertilizer. Thus, optimum use of water not only cuts GH emissions, but it also saves a lot of water. Along with these methods, rainwater harvesting (surface runoff into tanks/farm ponds), soil moisture retention (contour bunds, trenches, and pits to absorb rain), and groundwater recharge (repurposing old wells) will go a long way to ensure better use of limited water.

1.1.4 Agroforestry and related practices: Agroforestry refers to planting trees, crops, and raising animals on the same land, and is becoming more popular among land-use practices that can withstand climate change. Taking care of issues related to crop-tree competition and compatibility is an important consideration for this type of farming. Agroforestry makes farm ecosystems more diverse, which protects them from climate shocks, such as heavy rain and drought, which are becoming more common. It also helps control the local microclimate and keeps yields steady even when conditions are bad. Agroforestry practices increase biodiversity by creating different habitats, which is different from the single-crop fields that are common in large-scale farming. Recent studies from around the world have shown that agroforestry is efficient at capturing carbon from the air, in both the trees and the soil; it is thus an important approach to get rid of carbon dioxide on a large scale. Overall, agri-sylvi-pastoral systems can help in better utilization of available resources; they also provide extra benefits, such as healthier soil, better water retention, avoidance of risk, and improved overall sustainability in agriculture.

1.1.5 Renewable energy: Using solar and wind energy for irrigation and in the post-harvest processing of crops on farms has been shown to cut down both emissions and costs around the world. Studies show that solar-powered irrigation systems can cut greenhouse gas emissions around 95 percent, compared to pumps that run on diesel or electricity from the grid. Solar installations on the farm can cut down the energy needed for irrigation, and lower operating costs when done on a large scale. FAO has reported, through a global study, that irrigation alone is responsible for 15% of all greenhouse gas emissions from farms; switching to renewable energy sources can help alleviate this problem. Smart solar-powered

irrigation systems make energy use more efficient, while also supporting sustainable production, raising farmers' incomes, and improving food security globally.

1.2 Socioeconomic Factors

There are other related factors, social and economic, which impinge on the success of SA. These can be considered under three broad headings: (1) consumer diets and wastage of food; (2) family farming; and (3) wealth creation.

1.2.1 Consumer diets and wastage of food: Two of the quickest and most effective ways to cut down on emissions from the food system are (1) changing consumer behaviour towards adopting healthier, lower-impact diets; and (2) cutting down on food waste at farm, market, and home. The 2024 Food Waste Index (UNEP) says that homes are the biggest source of food waste around the world. In 2022, 60% of the 1.05 billion tonnes of food that was thrown away came from homes alone. This pattern, which can be seen everywhere, regardless of income, shows the importance of focussing efforts toward the following goals:

- Safe ways to store farm produce, using cold storage and transport more efficiently;
- Better coordination between market value chains; and
- Changes in human behaviour to keep food from going bad and making it easier to manage fresh foods.

Eating less red meat, avoiding highly processed foods, resource-use-intensive foods (such as Greek yoghurt), and choosing more plant-based proteins could cut global food-related emissions by around 17% and ease the strain we put on our land and water resources.

1.2.2 Family farming: The growth of industrial agriculture around the world has improved profits for farmers, but it has also had big effects on the environment. Among all farming methods, industrial farming hurts the environment most, destroys traditional farming knowledge, creates health hazards, increases the cost of production, and makes resource inequalities worse, especially for rural and indigenous communities. As a result, there are clear indications that going back to diversified family farming is an effective way to move forward with sustainable agriculture in certain areas.

Though there are fewer smallholder and family farms around the world, they still make up most farms and grow about a third of the world's food, often in areas where food is scarce or less accessible, especially for the rural poor. At the same time, as farm sizes get bigger in more developed areas because of high-input practices, farmers are stepping away from farming. For larger farms to be able to support themselves in a way that is likely to last, there must first be stable job opportunities for farm workers. On the other hand, farms are also getting fragmented, owing to local inheritance laws in many developing countries.

Family farmers, indigenous peoples, and local communities are increasingly important for adapting to climate change and making sure there is enough food for

all. They are important caretakers of traditional agriculture and food systems, while they use some new methods, especially in less industrialised areas, such as parts of Africa and South Asia, where they provide up to 80% of the food. Incidentally, we are in the middle of the United Nations Decade of Family Farming (2019-2028), a global initiative led by the FAO and International Fund for Agricultural Development (IFAD), which aims to highlight the crucial role of family farms in achieving food security, poverty eradication, and sustainable development by 2030. The family farming methods are important for resilience, such as protecting biodiversity. In the end, a country's food security depends on having enough food and other products.

1.2.3 Creation of wealth: A crucial question remains, which engages many minds: can the wealth of farmers be improved through SA? The answer is emphatically yes, it is possible and, in several cases, preferable, when compared to high-input agriculture. Here's how sustainable agriculture can benefit farmers economically over the long term:

- Reduced costs from reduced input, as sustainable practices rely more on locally available resources;
- Farmers are less dependent on market volatility, and thus assured of prices and income stability;
- Improved soil health leads to better water retention and resilience to droughts and floods;
- Sustainable and organic products can fetch premium prices, especially in urban and export markets;
- Diverse cropping systems and integrated farming reduce risks from inclement water, insect pests, and diseases, offering more stable income;
- Sustainable practices preserve natural resources, ensuring future productivity and income;
- Governments and non-governmental organisations (NGOs) now support sustainable farming with training, financial incentives, and market access; and
- The possibility of promoting ecotourism can bring better income to farm families.

Section 2: The Appeal of Short-Term Economic Gains

The strong desire for immediate financial gain usually drives farmers' decisions about what to grow and how to grow it. The need for quick money often means they choose instant financial security over agronomic practices that would make the land stay healthy and productive for a longer term. The appeal for short-term gains may stem from various reasons: (1) farmers' dependence on immediate income; (2) rapid returns from MA; and (3) most markets and credit mechanisms favour short-term returns. We consider these next, as they present certain challenges for the smallholder farmer in changing from MA to SA.

2.1 Farmer Dependence on Immediate Income

Farmers, especially smallholders in developing countries, require cash for day-to-day household expenses. For many farmers, the money from the sale of produce is the

only income, and hence it is critical to support their family, pay for children's schooling, medical care, and most importantly, repay their loans. They also require cash to buy inputs, namely seeds, fertilizers, and pesticides, and for hiring labour. This intense financial pressure makes them lean towards agricultural practices that provide quick and assured cash return. It also makes them vulnerable to fluctuating market prices. If the harvest is not as good as expected and fails due to any reason, it can cause a financial crisis that might force them to sell their property or fall into the debt trap.

2.2 Rapid Returns from Conventional High Input Methods

The constant need for ready cash leads to farming practices such as monocropping, where farmers dedicate large fields to a single, valuable crop (such as rice, corn, or wheat). Even in small villages, if a certain crop is known to bring in higher and faster profits, most farmers might choose to plant that same crop, creating an unofficial monoculture. Monocropping, when combined with the use of substantial amounts of chemical fertilizers and pesticides, helps farmers get good yields and immediate income in a single season. Using farm machinery (such as tractors and harvesters) lets them work larger areas and cut down on labour costs, speeding up the entire process to hit the best time to sell the produce in the market. Over time, these intensive methods harm the soil and reduce the biodiversity on the farm.

2.3 Markets and Credit Mechanisms Favour Short-term Returns

The focus on quick returns is strongly supported by the larger economic system. Because of government subsidies, which often apply mostly to specific and common crops, farmers tend to plant high-yielding varieties of staples with extensive use of inputs, as they will get a minimum support price (MSP). In addition, world market prices often dictate which crops are most profitable internationally, urging farmers everywhere to produce whatever is currently in high demand—typically large volumes of staple cereal crops. Crucially, loan structures—from big banks to small-scale lenders—are often designed to finance the purchase of seeds and fertilizer, with the full repayment expected soon after the harvest. This system inherently supports and finances farming methods that put a premium on short-term production and quick cash turnaround, rather than long-term care of the soil or the practice of SA methods, which might take longer to become profitable.

Summing Up

Understanding the underlying pressures shows how difficult it is for small farmers to shift to farming methods that are more sustainable and better for the environment, but which often bring in less immediate profit. Switching from a subsidized mono-cropping to diverse and sustainable farming requires institutional support during the transition where harvests might be smaller, the cost for organic inputs

might be higher, and where there is a need for new markets/consumers to be found. Without strong financial safety nets, a guaranteed market to sell the diverse crops, and technical support during the transitional period, the chances of farmer going bankrupt are too high. For a farmer, whose entire survival relies on the next harvest, choosing long-term sustainability over immediate financial survival is not a realistic option. Therefore, helping small farmers get the money and supplies they need is the most important intervention that policymakers should be focusing on.

SA is an imperative, and for it to succeed, global commitment from both governments and populations is essential. This involves adopting innovative practices such as precision farming, conservation agriculture, and agroforestry, alongside encouraging behavioural changes in dietary choices and waste reduction. Challenges do exist for the transition to SA, and these will be elaborated in **Part 2**.

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