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Evolving Strategies in Sustainable Agriculture: A Comprehensive Review

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ABSTRACT

An estimated 25-35% of global greenhouse gases are produced from agriculture. Modern agriculture also contributes to the loss of biological diversity, habitat loss, water pollution, degradation of soil quality, and loss of beneficial organisms including pollinators, microorganisms and animals that keep pests under control, but which pose a risk to human health through pesticide exposure and excess nitrogen & fluorine in drinking water. Sustainable agriculture, including practices such as organic farming and crop rotation, has the potential to alleviate many environmental problems and health risks associated with the modern industrial agricultural system.

Key words: Sustainable, Economic viability, Resources, Welfare, Crop Rotation, Cover Crop

Introduction

"Everything else may wait but not agriculture"-these word of Pt. Jawaharlal Nehru, our first prime minister bears ample testimony to the concerns of our national leadership towards strengthening agriculture. The farm productivity and production levels were quite low and import of food grains was a compulsion to meet the domestic needs of food items after the post independence era. Agriculture is the largest private enterprise in India (>10 crore farm holdings) considered lifeline of the Indian economy. It will be continued at least in the foreseeable future. It contributes nearly 17% of the national GDP. It also sustains livelihood of about 2/3rd of the population which accounts 52% of the national work force. Therefore it is forming the back bone of the agro based industry. Besides, agriculture is the social sector where non-trading concerns like food and nutritional security, employment and income generation, poverty elevation, gender equity, ecology and environment play a significant role.

The higher production of food, fiber, or other plant or animal products can be achieved with the help of sustainable agriculture. However toxic chemical such as pesticides and synthetic fertilizers, use of genetically modified seeds and practices that degrade soil, water and other natural resources may contribute the poor effects of inorganic farming on ecosystem. Sustainable agriculture is the finest way to overcome these adverse effects of food production. Basically, sustainable agriculture is production of food, fiber, or other plant or animal products using farming methods that protect the ecosystem which includes environment, human and animal. The goal of sustainable agriculture is to meet the requirement of food and other commodities of society without disturbing the ecosystem for future generations. Practitioners of sustainable agriculture seek to integrate three main objectives into their work: a healthy environment, economic profitability, and social and economic equity. The farmers, food processors, distributors, retailers, consumers and waste managers can play a vital role in ensuring a sustainable agricultural system by adopting eco-friendly practices. Growers may use methods to promote soil health such as zero tillage or no tillage, minimization of irrigation water used, and minimization of soil pollution through accumulation of toxic chemicals in the farm soil. Consumers and retailers concerned with sustainability can look for "values-based" foods promoting farmers livelihood that are grown using eco-friendly methods that strengthen the local economical conditions. Moreover researchers in sustainable agriculture often cross disciplinary lines with their work: combining biology, economics, engineering, chemistry, community development, and many other. However, sustainable agriculture is more than a collection of practices. It is also process of negotiation: a push and pull between the sometimes competing interests of an individual farmer or of people in a community as they work to solve complex problems about how we grow our food and fiber. Sustainability rests on the principle that we must meet the needs of the present without compromising the ability of future generations to meet their own need.

Meaning of Sustainable Agriculture

Sustainable agriculture is the use of farming systems and practices which maintain or enhance

1. The economic viability of agricultural production;
2. The natural resource base; and

3. Other ecosystems which are influenced by agricultural activities.

This definition can be supplemented by some fundamental principles of sustainable agriculture:

That farm productivity is enhanced over the long term:

1) That adverse impacts on the natural resource base and associated ecosystems are ameliorated, minimized or avoided;
2) That residues resulting from the use of chemicals in agriculture are minimized;
3) That net social benefit (in both monetary and non-monetary terms) from agriculture is maximized; and
4) That farming systems are sufficiently flexible to manage risks associated with the vagaries of climate and markets.

Sustainable Agriculture: The Basic Concept

The word "sustain," from the Latin sustinere (sus-, from below and tenere, to hold), to keep in existence or maintain, implies long-term support or permanence. As it pertains to agriculture, sustainable describes farming systems that are "capable of maintaining their productivity and usefulness to society indefinitely. Such systems must be resource-conserving, socially supportive, commercially competitive, and environmentally sound. "Sustainable agriculture" was addressed by Congress in the 1990 "Farm Bill" [Food, Agriculture, Conservation, and Trade Act of 1990 (FACTA). Under that law, "the term sustainable agriculture means an integrated system of plant and animal production practices having a site-specific application that will, over the long term:

• Satisfy human food and fiber needs;

• Enhance environmental quality and the natural resource base upon which the agricultural economy depends;

• Make the efficient use of non-renewable resources and on-farm resources;

• Sustain the economic viability of farm operations;

- Enhance the quality of life for farmers and society as a whole."

Objectives of Sustainable Agriculture:

- To make best use of the resources available.
- To minimize use of non-renewable resources.
- To protect the health and safety of farm workers, local communities and society.
- To protect and enhance the environment and natural resources.
- To protect the economic viability of farming operations.
- To provide sufficient financial reward to the farmer to enable continued production and contribute to the well-being of the community.
- To produce sufficient high-quality and safe food.
- To build up technology, knowledge and skills in ways that suit local conditions and capacity.

Advantages of Sustainable Agriculture

Environmental Preservation

Sustainable farms produce crops and raise animals without relying on toxic chemical pesticides, synthetic fertilizers, genetically modified seeds,or practices that degrade soil, water, or other natural resources. By growing a variety of plants and using techniques such as crop rotation, conservation tillage, and pasture-based livestock husbandry, sustainable farms protect biodiversity and foster the development and maintenance of healthy ecosystems.

Protection of Public Health

Food production should never come at the expense of human health. Since sustainable crop farms avoid hazardous pesticides, they're able to grow fruits and vegetables that are safer for consumers, workers, and surrounding communities. Likewise, sustainable livestock farmers and ranchers raise animals without dangerous practices like use of non-therapeutic antibioticsor arsenic-based growth promoters. Through careful, responsible management of livestock waste, sustainable farmers also protect humans from exposure to pathogens, toxins, and other hazardous pollutants.

Sustaining Vibrant Communities

A critical component of sustainable agriculture is its ability to remain economically viable, providing farmers, farmworkers, food processors, and others employed in the food system with a livable wage and safe, fair working conditions. Sustainable farms also bolster local and regional economies, creating good jobs and building strong communities.

Upholding Animal Welfare

Sustainable farmers and ranchers treat animals with care and respect, implementing livestock husbandry practices that protect animal health and wellbeing. By raising livestock on pasture, these farmers enable their animals to move freely, engage in instinctive behaviors, consume a natural diet, and avoid the stress and illness associated with confinement.

Components of Sustainable Agriculture

Soil management

A common philosophy among sustainable agriculture practitioners is that a "healthy" soil is a key component of sustainability; that is, a healthy soil will produce healthy crop plants that have optimum vigor and are less susceptible to pests. While many crops have key pests that attack even the healthiest of plants, proper soil, water and nutrient management can help prevent some pest problems brought on by crop stress or nutrient imbalance. Furthermore, crop management systems that impair soil quality often result in greater inputs of water, nutrients, pesticides, and/or energy for tillage to maintain yields.

In sustainable systems, the soil is viewed as a fragile and living medium that must be protected and nurtured to ensure its long-term productivity and stability. Methods to protect and enhance the productivity of the soil include:

i. Using cover crops, compost and/or manures

ii. Reducing tillage

iii. Avoiding traffic on wet soils

iv. Maintaining soil cover with plants and/ or mulchesConditions in most soils (warm, irrigated, and tilled) do not favor the buildup of organic matter. Regular additions of organic matter or the use of cover crops can increase soil aggregate stability, soil tilth, and diversity of soil microbial life.

Protecting Water Quality and Supply

Maintaining water quality and supply is one of the most important elements of sustainable agriculture. Keeping harmful contaminants such as pesticides and nitrates out of the water table helps crop growth and ensures the continued arability of the land.Carefully managing water consumption is also essential, especially in arid climates where drought is common. Farms can be developed to be drought-resistant by using low-volume irrigation systems, growing drought-tolerant crops and improving water conservation measures. Sometimes suspending growing operations altogether may be the best course of action. The consequences of overdrawing limited surface water supplies in times of drought can be severe, including permanent aquifer collapse and increased salinity.

Land use

Conversion of agricultural land to urban uses is a particular concern, as rapid growth and escalating land values threaten farming on prime soils. Existing farmland conversion patterns often discourage farmers from adopting sustainable practices and a long-term perspective on the value of land. At the same

time, the close proximity of newly developed residential areas to farms is increasing the public demand for environmentally safe farming practices. By helping farmers to adopt practices that reduce chemical use and conserve scarce resources, sustainable agriculture research and education can play a key role in building public support for agricultural land preservation. Educating land use planners and decision-makers about sustainable agriculture is an important priority.

Ecological Concerns

Agriculture profoundly affects many ecological systems. Negative effects of current practices include the following: Decline in soil productivity can be due to wind and water erosion of exposed topsoil; soil compaction; loss of soil organic matter, water holding capacity, and biological activity; and salinization of soils and irrigation water in irrigated farming areas. Desertification due to overgrazing is a growing problem.

Agricultural practices have been found to contribute water pollutants that include: sediments, salts, fertilizers (nitrates and phosphorus), pesticides, and manures. Pesticides from every chemical class have been detected in groundwater and are commonly found in groundwater beneath agricultural areas; they are widespread in the nation's surface waters. Eutrophication and "dead zones" due to nutrient runoff affect many rivers, lakes, and oceans. Reduced water quality impacts agricultural production, drinking water supplies, and fishery production.

Environmental ills include over 400 insects and mite pests and more than 70 fungal pathogens that have become resistant to one or more pesticides; stresses on pollinator and other beneficial species through pesticide use; loss of wetlands and wildlife habitat; and reduced genetic diversity due to reliance on genetic uniformity in most crops and livestock breeds.

Agriculture's link to global climate change is just beginning to be appreciated. Destruction of tropical forests and other native vegetation for agricultural production has a role in elevated levels of carbon dioxide and other greenhouse gases.

Renewable Energy Production and Consumption

Many farms and agricultural operations are dependent on non-renewable energy from fossil fuels like coal and petroleum. These resources are finite and cannot be used indefinitely. Using fossil fuels for energy production also causes carbon emissions and contributes to global climate change–which may have catastrophic consequences for agriculture. Transitioning to renewable sources of energy such as wind, solar and biomass is an important step in addressing these concerns, as well as working toward increased energy efficiency. More and more farms are including solar cells and biomass generators for heat and power, reducing the impact of energy production and consumption for agriculture.

Plant and Animal Production Practices

Plant and animal selection are crucial to sustainable agriculture. The wrong combination or an excess of a particular crop or choice of livestock can have devastating effects on the environment that may compromise sustained growth. Careful management of the effects of cultivating plants and livestock are important to ensuring the long-term success of any agricultural endeavor.That means choosing suitable crop species and livestock as well as diversifying crops, maintaining and enhancing soil quality, and efficient use of non-harmful, ideally renewable chemicals or organics.

Labor Practices and Social and Economic Equity

The social and economic costs of inequitable labor practices are enormous. Unfortunately, in the world of agriculture, unfair labor practices are commonplace. By establishing better labor laws and practices, the social and economic impacts of agriculture can be mitigated and the exponentially growing need for more and more public services can be reduced to a sustainable level. Developing rural communities is also an important consideration in this regard. Many are severely impoverished and lack access to adequate employment, healthcare, and education. Working towards sustainable agriculture means addressing the socio-economic ills in these communities to help them thrive and secure their continued vitality.

Sustainable Agriculture techniques

Sustainable agriculture provides high yields without undermining the natural systems and resources on which productivity depend. Farmers who take a sustainable approach work efficiently with natural processes rather than ignoring or struggling against them – and use the best of current knowledge and technology to avoid the unintended consequences of industrial, chemical-based agriculture. One important result is that farmers are able to minimize their use of pesticides and fertilizers, thereby saving money and protecting future productivity, as well as the environment. Below are some of the most common sustainable agriculture techniques employed by farmers today to achieve the key goals of weed control, pest control, disease control, erosion control and high soil quality:

- Crop Rotation
- Cover Crops
- Soil Enrichment
- Natural Pest Predators

- Biointensive Integrated Pest Management

Crop Rotation

Crop rotation growing different crops in succession in the same field is one of the most powerful techniques of sustainable agriculture, and avoids the unintended consequences of putting the same plants in the same soil year after year. It is a key element of the permanent and effective solution to pest problems because many pests have preferences for specific crops, and continuous growth of the same crop guarantees them a steady food supply, so that populations increase. For example, right now European corn borers are often a significant pest in the United States because most corn is grown in continuous cultivation or in two-year rotations with soybeans. Four- or five-year rotations would control not only corn borers, but many other corn pests as well. In fact, rotation reduces pest pressure on all the crops in the rotation by breaking the pest reproductive cycles.In rotations, farmers can also plant crops, like soybeans and other legumes, which replenish plant nutrients, thereby reducing the need for chemical fertilizers. For instance, corn grown in a field previously used to grow soybeans needs less added nitrogen to produce high yields.

Cover Crops

Many farmers also take advantage of the benefits of having plants growing in the soil at all times, rather than leaving the ground bare between cropping periods, which produces unintended problems. The planting of cover crops such as hairy vetch, clover, or oats helps farmers achieve the basic goals of:

- Preventing soil erosion

1. Suppressing weeds, and Enhancing soil quality
2. Using appropriate cover crops is worth the extra effort because it reduces the need for chemical inputs like herbicides, insecticides, and fertilizers.

Soil Enrichment

Soil is arguably the single most prized element of agricultural ecosystems. Healthy soil teems with life, including many beneficial microbes and insects, but these are often killed off by the overuse of pesticides. Good soils can improve yields and produce robust crops less vulnerable to pests; abused soils often require heavy fertilizer application to produce high yields. Soil quality can be maintained and enhanced in many ways, including leaving crop residues in the field after harvest, plowing under cover crops, or adding composted plant material or animal manure.

Natural Pest Predators

Understanding a farm as an ecosystem rather than a factory offers exciting opportunities for effective pest control. For example, many birds, insects, and spiders are natural predators of agricultural pests. Managing farms so that they harbor populations of pest predators is a sophisticated and effective pest-control technique. One of the unfortunate consequences of intensive use of chemical pesticides is the indiscriminate killing of birds, bats, and other pest predators.

Bio intensive Integrated Pest Management

One of the most promising technologies is the control of pests through integrated pest management (IPM). This approach relies to the greatest possible extent on biological rather than chemical measures, and emphasizes the prevention of pest problems with crop rotation; the reintroduction of natural, disease-fighting microbes into plants/soil, and release of beneficial organisms that prey on the pests. Once a particular pest problem is identified, responses include the use of sterile males, biocontrol agents like ladybugs. Chemical pesticides are only used as a last resort.

Approaches of Sustainable Agriculture

Sustainable agriculture has been practiced for many decades and encompasses a tremendous number of different approaches described by many different names.Many of the approaches in conventional agriculture (minimum tillage, chemical banding) would fall into the "efficiency" category. They demonstrate a reduction in resource use and associated negative environmental impact, and in many cases a reduction in input expenses for the farmer. They represent, however, only an initial step towards a truly sustainable system.Efforts to substitute safe products and practices (botanical pesticides, bio-control agents, imported manures, rock powders and mechanical weed control) are also gaining popularity. Despite the reduced negative environmental damage associated with them, they remain problematic. Botanical pesticides also kill beneficial organisms, the release of bio-controls does not address the question of why pest outbreaks occur dependence on imported fertilizer materials makes the system vulnerable to supply disruptions and excessive cultivation to control weeds is detrimental to the soil.

The systems that focus on redesign ofthe farm are the most sophisticated, generally the most environmentally and economically sustainable, over the long term. These farm systems recycle resources to the greatest extent possible, meaning that little is wasted, few pollutants are generated, and input costs are reduced substantially. For example, chicken and orchard operations have been successfully integrated. The manure is used as a fertilizer, the chickens eat pests that attack the fruit, the feed bill for the chickens is greatly reduced, and the eggs and/or meat can be consumed or sold. Three to seven year crop

rotations can be designed that minimize tillage, use legumes and green manures to maintain soil fertility, prevent pest and disease outbreaks, and provide a diverse diet for livestock. Pigs and goats can be used to renovate wooded lands in preparation for sheep pasture. The pigs and goats replace the petrochemical energy that would be consumed in machines, herbicides and fertilizers. All these practices involve redesigning the farm (as well as the institutional supports, which will be discussed later). As in conventional agricultural systems, the success of sustainable approaches is very dependent on the skills and attitudes of the producers. The degree to which different models of such farms are sustainable is very variable, and is dependent on the physical resources of the farmer, and the degree deficiencies in support farm, the talents and commitment of the support available. The current from government, universities, and agricultural professionals means that farmers must often rely on their own talents and commitment.

Challenges in Sustainable Agriculture

Agriculture is perhaps the most outstanding issue and challenge for sustainability. To attain the 'sustainable development' goal requires urgent actions on three fronts - the ecological, the social and the economic. There is a looming crisis and possible calamity developing in this all-important sector that must be urgently addressed, as it impacts on the livelihoods of most of the world's people and everyone else's food needs.

Agriculture is facing three major problems and choices:

(a) Ecology/Technology: Which technology to base the future of world agriculture on? As the chemical-based model is faltering, the private sector and global establishment are looking to genetic engineering as the way ahead. But all the signs are that ecological farming is superior, not only for the environment, but also for gains in productivity and farmers' incomes. It has not been given the chance to prove itself. It should be.

(b) The global economic framework: The economic environment has turned extremely bad for developing countries' small farmers. International Monetary Fund (IMF)-World Bank structural adjustment has put pressure on poor countries to liberalize food imports and abandon subsidies and government marketing boards. The World Trade Organization (WTO) Agreement on Agriculture (AoA) enables rich countries to raise their subsidies and set up astonishingly high tariffs, while punishing developing countries (which cannot increase their subsidies, and which have to liberalize their imports further). Commodity prices have slumped. These three factors are threatening the survival of developing countries' farms and farmers. The entire framework of global and national economic policies for agriculture has to be thoroughly revamped.

(c) Land for the farmers: Many small farmers are poor and some are becoming poorer. A main reason is unequal land distribution, where small farmers have little land securityor access and lose a large part of their income to landowners. Land reform is urgently required and landless farmers are fighting for their rights. But the landowners in most countries have political clout and are resisting change.

All three issues have to be resolved, and in an integrated way, if sustainable agriculture is to be realized. Otherwise there will be an absolute catastrophe, especially if the wrong choices are made.

Conclusion

The agricultural sector has multiple roles in developing countries: to help ensure food security, anchor rural development, provide resources for the livelihood and adequate incomes of a majority of people, all without destroying the environmental base. There are thus two inextricably linked components, the social and environmental, to agricultural sustainability.

The erosion of the spirit and practice of international cooperation, especially on a North-South basis, is having serious repercussions on agriculture and on rural development in developing countries. This erosion is most noticeable in the decline in aid.It is thus imperative that a change of mindset takes place, to review the present damaging framework and build a new paradigm of policies that can promote sustainable agriculture. Sustainable agriculture is beneficial for the environment by maintaining soil quality, reducing soil degradation and erosion, and saving water. In addition to these benefits, sustainable agriculture also increases biodiversity of the area by providing a variety of organisms with healthy and natural environments to live in.

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