Chapter 4
Climate Change and Sustainability of Agriculture in Bangladesh

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Abstract Bangladesh is forced to import food from the international market or resort to foreign aid. Droughts or cyclones both disrupt agricultural output rapidly and thus leave a lot of families helpless. They also affect domestic food prices which makes it difficult for the majority of the middle-income families within the urban areas. In Bangladesh, food security has been one of the major national priorities for last few decades, but the target has always been interrupted by the climate change and for resource constraints. Present section of this chapter will highlight the major effects of climate change in the food production and the national resources constraints to address the food security. However, major constraints in terms of food security in Bangladesh attributed to cultivable land scarcity, irrigation water scarcity in summer, lack of technological knowledge, lack of climate adaptive crop variety, lack of institutions and professionals as well as social and cultural constraints. Richer farmers can afford modern machineries, genetically modified crop seeds and chemical fertilizers. This results in efficient farming, higher yield from a unit plot of land or better utilization of larger farmlands. This not only produces good quality and large quantity of output, but also means that the produces can be sold at cheaper rates at the local market, or can be processed and exported for higher rates. Farmers who cannot afford such technology are at a disadvantage.

Keywords Climate change · Food security · Crop variety · Sustainable agriculture · Bangladesh

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Introduction

Bangladesh, primarily being a low-lying country with an intricate network of rivers, benefits from having alluvium-rich soil are good for farming. As such, communities grew around the major river networks of the Ganges, Brahmaputra and Meghna, and their associated tributaries. These rivers have fertile floodplains which allow for high crop yield. A lot of subsistence-based farmers depend on the river network for their day-to-day food source. This developed an almost pendulum liked back and forth interaction with the rural community and nature. River networks frequently cause flooding which disrupts livelihood, but the receding flood leaves behind silt and alluvium-rich soil which in turn increases productivity for the next season's harvest. The benefits seem to outweigh the risks which is why so many rural communities cluster around the rivers.

The importance of agriculture is evident from its contributions to both Bangladesh's GDP and employment level. Almost 20% of the total GDP stems from agriculture while simultaneously employing 60% of the population. Furthermore, around 60% of the total landmass is also considered to be arable.

Agricultural produces in Bangladesh range from rice, which is primarily for domestic consumption, to jute and tea, which are the main export crops. In addition to these three main crops, farmers also produce sugarcane, tobacco, cotton, various fruits such as jackfruit, banana, potatoes, pineapples, etc. for local consumption. Since rice is a staple food for Bangladesh, they are produced in plenty. Both rice and wheat production plays a crucial role in achieving self-sufficiency, but unpredictable weather condition causes occasional interference. As such, Bangladesh is forced to import food from the international market or resort to foreign aid. Droughts or cyclones both disrupt agricultural output rapidly and thus leave a lot of families helpless. They also affect domestic food prices which makes it difficult for the majority of the middle-income families within the urban areas.

While our ancestors relied on hunting and gathering during the dawn of time, it was only sufficient to support a small group of population. They always had to be on the move in order to not exhaust the supplies of a particular area. As a result, it was difficult to have a thriving population as food security was lacking. However, once they realized that it is far more efficient to settle down in one particular location and grow their own food, they suddenly began to have a more stable life. The advent of agriculture meant that a population could finally settle down and not worry about supplies as much as before. This caused the start of early civilization around river networks that had fertile soil near its floodplains.

As Malthusian theory have stated, population grows exponentially while agricultural outputs expand arithmetically. This was valid during its time, where technological innovation could not feasibly be taken into account. However, with industrial revolution and its subsequent green revolution, the prediction no longer stayed true. Technological innovation meant that some of the labor involved in food production could be replaced by machineries, and with the same amount of land, more yield could be produced with the adoption of intensive practices.

For low-income countries, such as Bangladesh itself, the advent of green revolution marked the time where reliance on imported food could be lessened and even local produce could outpace local consumption. This meant that agricultural products could, for the very first time, be exported and act as a source of foreign revenue.

However, the effects of the green revolution did not manifest itself equally across a countries geography. The technology and synthetic nature of the revolutions output meant that it only benefited the richer segment of the producers. Small, subsistence-based farmers were often deprived of the benefits and instead were at a competitive disadvantage as they could not keep up with the high initial costs of production. This inequality meant that a large portion of the farming community were excluded from the benefits and had to rely on a poor resource base. Furthermore, the intensive application of synthetic practices meant that nutrients depleted rapidly and caused ecological deterioration and harm. While the overall output of the country has increased, the green revolution widened inequality and brought its output at the expense of environmental stability. Developments in agriculture, livestock husbandry and fisheries since past five decades have attempted to keep pace with the burgeoning population base in Bangladesh. Especially the agricultural progress witnessed in the world over in the past four decades has been impressive. The food and fiber productivity improved due to adoption of innovative technologies, viz. adoption of high-yielding varieties of crops, irrigation, increased fertilizer and use of plant protection chemicals, mechanization of farm operations and other technology-intensive practices coupled with public policies favoring maximizing production. Even the committed critics of green revolution should agree to the fact that the green revolution witnessed in Bangladesh enabled the country to overcome serious shortage of food and a precarious ship to mouth existence. The technologies were input intensive which were mostly off farm and synthetic in nature, which led to the deterioration of soil health, ground and surface water quality and narrowing of the natural resource base. The revolution was uneven in extending its perceived benefits and excluded a large chunk of farm community struggling to survive on poor resource base. Continuous mining of natural resources over the decades no doubts resulted in increase in production but at the same time lead to degradation of natural resources. As a result, the productivity levels achieved have not been wholly sustainable ecologically, environmentally and economically and non-remunerative as well. Reduction of resource base on one hand and increase in cost of production/cultivation on the other necessitated the importance of protecting and harnessing natural resources (Fig. 4.1). The environmental protection movements leaded by the environmental activism worldwide succeeded in bringing in to focus issues such as soil and water degradation, narrowing of genetic base, pollution with plant protection chemicals, nitrification of water bodies and increasing costs of production. Bangladesh also has very proactive environmental activism highlighting these issues.

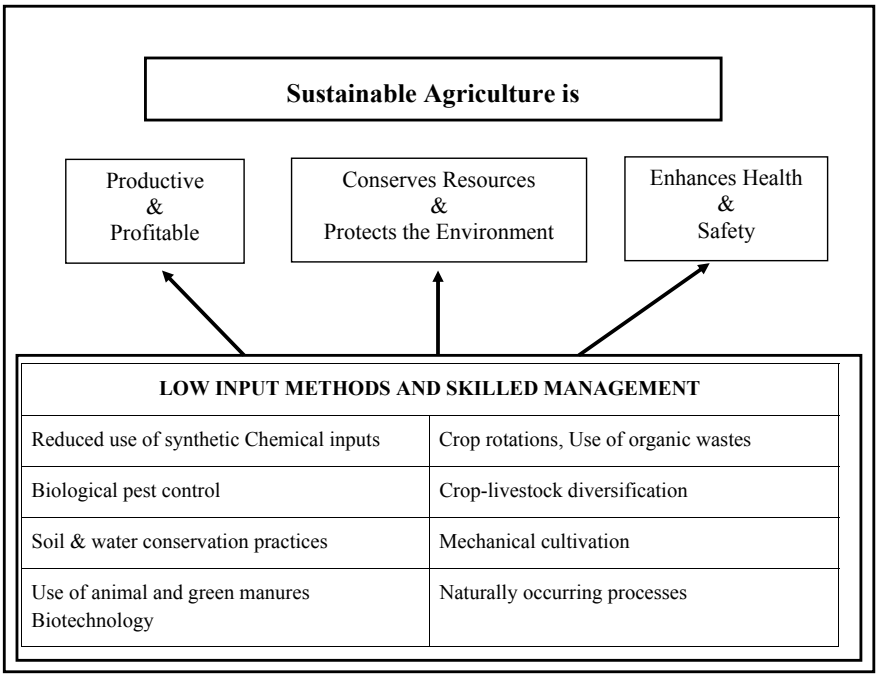

Fig. 4.1 Goals and components of sustainable agriculture

Concept of Sustainable Agriculture

Sustainable agriculture is a concept of farming directed toward maintain or improving the natural resource base while harnessing the same for the production of food, fiber and feed as well as other agro based commodities including livestock, fisheries and aquaculture products. The practices associated with sustainable agriculture involves production of clean foods and other products while sustaining soil health and productivity, water quality, biodiversity and above all economically viable and socially acceptable. The sustainable agriculture practices should have minimum or no negative impact on ecology, environment and quality of human life.

There are different concepts of sustainable agriculture, but none is generally accepted. It embraces several forms of non-conventional agriculture that are often called organic, alternative, ecological or low input. However, from economic and ecological perspectives, two basic criteria must be met if agriculture has to be sustainable in the long term. These are.

Sustainable farming uses some form of integrated pest management for pest control, and this can include the use of chemical pesticides that are not used by organic farmers. Thus, sustainable agriculture does not mean a return to the farming methods of the late 1800's. Rather, it combines traditional techniques that stress conservation with modern technologies, such as improved seed, modern equipment

for low-tillage practices, integrated pest management that relies heavily on principles of natural or biological control weed control that depends on crop rotations and manual weeding. Sustainable farms use wind or solar energy instead of purchased energy and use organic animal manure and nitrogen-fixing legumes as green manure to maintain soil fertility, as much as possible, thereby minimizing the need for purchased inputs. The uses of genetically engineered crop varieties are not excluded by sustainable farming. The emphasis is on maintaining the environment, not on rules about what can or cannot be done. Profits from sustainable farms can exceed those of conventional farms.

Innovative farmers have developed many alternative farming methods and systems. These systems consist of a wide variety of integrated practices and methods suited to the specific needs, limitations, resource bases and economic conditions of different category of farmers. To make wider adoption of sustainable agriculture, farmers need to receive information and technical assistance in developing better management skills.

Definitions Sustainable Agriculture

Sustainable agriculture recommends a range of practices, which address many problems that arise due to the problems of modern agriculture such as loss of soil productivity, impacts of agricultural pollution, decreased income due to high production costs, and minimal or uneconomic returns.

Lockets (1988): Defined sustainable agriculture as a time dimension and the capacity a farming system to endure indefinitely.

Gracet (1990): Defined sustainable agriculture as a system of agriculture that is committed to maintain and preserve the natural resource base of soil, water and atmosphere ensuring future generations the capacity to feed them with an adequate supply of safe and wholesome food.

Crosson (1992): A sustainable agriculture system is one that can indefinitely meet demands for food and fiber at socially acceptable economic and environment cost.

However, commonly accepted definition of sustainable agriculture as production and distribution system that:

- Achieves the integration of natural biological cycles and controls
- Protects and renews solid fertility and natural resource base
- Reduces the use of non-renewable resources and purchased (external and off-farm inputs) production inputs
- Optimizes the management and use of on-farm inputs
- Provides an adequate and dependable income
- Promotes opportunities in family farming and farm communities

- Minimizes adverse impacts on health, safety with life, water quality and the environment
- Provides on-farm employment to the rural small and marginal farmers.

A comprehensive definition of sustainable rural development including farming systems offered by FAO in 1988 as: "Sustainable rural development is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner so as to assure the attainment and continued satisfaction of human needs for the present and future generations. Such sustainable development, in the agriculture, forestry and fishery sectors, conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable."

Goals of Sustainable Agriculture

Sustainable agriculture is any system of food or fiber production that systematically pursues.

- A incorporation of natural processes such as nutrient cycling, biological nitrogen fixation and pest predator relationships into agricultural production processes
- A reduction in the use of off-farm, external and non-renewable inputs (synthetic) with the greatest potential to harm the environment or the health of farmers and consumers and a more targeted use of remaining inputs used with a view to minimize variable costs
- Access to productive resources and opportunities, and progress toward more socially just forms of agriculture
- Use of biological and genetically potential of plant and animal species
- A judicious match between cropping pattern, environmental constraints of climate and landscape to ensure long-term sustainability of current productivity levels
- A greater and productive use of local knowledge and practices, including innovation in approaches not yet fully understood by scientists but widely understood and adopted by farmers
- A full participation of farmers and rural people in all processes of problem analysis and technology development, adoption and extension
- Profitable and efficient production with an emphasis on integrated farm management and conservation of soil, water, energy and biological resources.

The ultimate goal of sustainable agriculture is to maximize the benefits from the existing agricultural assets and minimize the threats to the environment from the current practices of technology-intensive agriculture directed only toward production maximization and profits.

Differences Between the Contemporary and Sustainable Types of Agriculture

Contemporary Agriculture

- System simplification/monoculture
- Specialized agriculture (economically vulnerable)
- Soil is considered just as a medium
- Feed the plant directly but not the soil
- Linear flow of nutrients/energy
- Reductionist.

Sustainable Agriculture

- System of production diverse not restricted by monoculture of crops
- Recycling of nutrient pool for crop
- Feed and nurture the soil and not the crop
- Holistic approach to farm productivity.

Positive Aspects and Factors Which Enhance Modern or Sustainable Agriculture

Modern Agriculture

- High yield/high and fast returns/profit oriented
- Increased mechanization
- Scope for intensive cropping
- Better compatibility through genetic homogeneity in inter/mixed cropping
- New varieties of plant breed (pest/disease tolerant)
- Maximum utilization of land and water
- Meeting the need of sufficient and fast food production
- Caters to habituation of food through monoculture
- Immediate and direct supply of nutrients to the plant through chemical fertilizers (NPK). Quick responses to inputs, fertilizers, chemicals
- Better pest, disease, weed control

- Package of practices for different locations, situations, crops, agro climatic regions
- Targeted yields evolved and recommended.

Sustainable Agriculture

- Affordability by any farmer
- No sophisticated/imported and special technology is necessary
- Environmental conservation and protection
- Healthy atmosphere/healthy food
- Prevent/avoid ecological degradation
- Increasing stability and status of soil fertility
- Security more through higher levels of disease and pest resistance
- Recycling of nutrients
- Substance of soil fertility through organic recycling
- Diversity
- Inter dependency
- Efficient use of natural resources
- Self-sustaining.

Negative Aspects, Problems, Barriers and Issues

Modern (Technology Intensive) Agriculture

- Short-term benefit, operates law of diminishing returns
- Depletion of nutritional base of the soil, water and atmosphere quality
- Environmental pollution due to use of chemicals (water, soil, environmental)
- Health hazards due to entry of pesticides, toxins, antibiotics, heavy metals in to food chain
- High cost of production
- Increasing dependency on external inputs
- Less diversification manifested through disappearance of genetic races because of monoculture leading to risks such as loss of biodiversity, pest and disease resistance and resurgence due to production of "unclean" food from the overall public health point of view
- Poor quality of produce
- Economic disparity in the society widens. Rich becoming richer and poor becoming more poorer

- Operates against principles of nature and ecology
- Natural parasites, predators and beneficial insects are adversely affected and totally disappear over a period of time.

Sustainable Agriculture

- Takes longer time to realize the benefits of regenerative farming
- The change is gradual
- Relatively difficult to motivate farmers for change initially but once convinced adoption easy
- Comparatively labor-intensive—needs proper planning for allocation/use of available resources
- Initial yield is low.

Lack of infrastructures and systems for documentation of indigenous knowledge and techniques, and inappropriate extension services for propagation. Lack of recognition, acknowledgement, motivation and incentives from the state. Financial assistance and back up, particularly to a small farmer is low, in comparison to what is available for adopting modern agriculture (subsidies inputs).

Elements of Sustainable Agriculture

Sustainable agriculture consists of elements, which are common in many regions. But the methods to improve their sustainability may vary from one agro ecological region to another. However, there are some common sets of practices among farmers trying to take a more sustainable approach by use of on-farm or local resources. However, each of them contributes to a greater extent to realize long-term farm profitability, environmental stewardship and quality of life.

(A) Soil conservation: Soil conservation methods including contour cultivating, contour bunding, graded bunding, vegetative barriers, strip cropping, cover cropping, reduced tillage, etc. help prevent loss of soil due to wind and water erosion.

(B) Crop diversity: Increased crop or biodiversity on farm can help reduce risks from extremes in weather, marketing conditions and pest disease incidences. The increased diversity of crop and other plants such as trees, shrubs and pastures also can contribute to soil conservation habitat protection and increased populations of beneficial insects.

(C) Nutrient management: Integrated management of essential nutrients can improve and sustain soil fertility and protect environment. Increased use of on-farm low-cost inputs such as organic manures, composts, green manures and crop residues not only reduces cost of production but also rejuvenates soil health.

(D) Integrated pest management (IPM): It is a sustainable approach to manage pests by aptly integrating the available plant protection methods like cultural, physical, mechanical biological and chemical methods, which optimizes the production costs besides maintaining environmental balance.

(E) Water quality and water conservation: Practices like zero tillage, deep plowing, and mulching and microirrigation techniques and mulching can help to optimize the water consumption or requirement besides conserving and augmenting the soil moisture on long-term basis. It also helpful in protecting the quality of drinking water and surface water.

(F) Agro forestry: A combination of silvipastoral, agri-silvipastoral, agri-horticulture, horti-silvipastoral, alley cropping, ley farming, etc. that can help conserve soil and water and profitability. Also leads to supply of fuel wood, horticultural products and achieve balanced nutrition to rural people.

(G) Marketing: Improved marketing facilities can ensure remunerative and sustainable returns to farmers. Direct marketing of produce can exclude intermediaries and ensures higher returns and malpractices.

Low External Input Sustainable Agriculture (LEISA)

Low external input supply agriculture (LEISA) is a component of sustainable agriculture. It can be defined as production activities which optimize the use of locally available resources by maximizing the complementary and synergetic effects of different components of farming system.

LEISA is based on a preventive approach wherein the problem is tackled at its roots as opposed to the more symptom curing nature of modern/chemical agriculture. LEISA is more labor intensive and often based on local knowledge and production systems.

Criteria for LEISA

Ecological Criteria

- Balanced use of nutrients
- Efficient use of water, energy and genetic resources
- Minimal/need-based external inputs
- Minimal negative environmental impact.

Economic Criteria

- Sustained farmer livelihood system
- Competitiveness
- Efficient use of production factors
- Low relative value of external inputs.

Social Criteria

- Widely acceptable and equitable adoption potential especially among small farmers
- Reduced dependency on external institutions
- Respecting and building ITK, beliefs and value system
- Contribution to employment generation.

Factors Influencing Ecological Balance in Sustainable Agriculture

Major factors which influence the resource base and ecological balance in sustainable agriculture are.

Soil-Related Factors

- Accelerated soil erosion and degradation
- Deforestation
- Siltation of reservoirs.

Irrigation-Related Factors

- Rise in ground water table and water logging
- Soil salinization and alkalization

- Overexploitation of ground water and reduction in ground water resources, i.e., depletion of water table.

Agro Chemical Pollution

- Fertilizer pollution
- Pesticide pollution.

Environmental Pollution

- Greenhouse gases
- Impact on ozone layer
- Methane emissions from soil and livestock husbandry.

Characteristics of Bangladesh Traditional Agriculture

Traditional agriculture or subsistence-based agriculture is primarily based on getting the most yield possible from a small plot of land. Since most of the land is inherited and is divided among successors, subsequent generations receive smaller and smaller plots of land. This means that to maintain a steady source of yield, more intensive techniques need to be employed. Thus, the use of both organic and chemical fertilizers is employed, irrigation is used, additional labor force is employed, etc. This is to squeeze as much yield as possible from a limited amount of land area.

For this reason, cropping intensity in Bangladesh in extremely high at around 179%. This refers to how much yield can be obtained from a certain amount of land. Moreover, around 56% of agricultural land is irrigated. While there are many river networks to help water the farms, these networks are not spread evenly across the country. Thus, the drier regions benefits from having irrigated water supply.

The intensive nature of agriculture is evident from the land-to-man ratio of only 0.06 ha. Most of this land is inherited, and this results in a very fragmented land supply. Fragmentation results in wasted land near the edges due to the presence of hedges, fences or barriers and thus the usable land area is even smaller.

One interesting point of note is the social structure around rural communities. Historically, they had a large family with many children. A large family meant that more labor force to help out with agricultural activities which meant that a higher

output could be extracted from the same plot of land. However, when it came to inheritance, the same plot of land had to be divided among many individuals which reduced future output potential as the land became fragmented.

This high dependence on manual labor is due to the fact that most of these farmers are not rich enough to afford modern machineries and mechanized farms. Instead, these farms are run through the use of simple equipment and are mostly animal driven. The manure from the domesticated animals are used as fertilizers and if the soil quality is poor then chemical fertilizers are used. However, reinvestment into the farms tend to be low as one seasons output can be used as the next seasons input. Reinvestment is also kept low in order to minimize expenditure as the output from these farms tend to produce few surplus. Whatever surplus are made though, are sold at the local market. Since these are unprocessed outputs, they do not fetch high prices and thus are sold cheaply. Furthermore, the lack of differentiation between sellers mean that competition can be fierce which keeps the costs low. All of this means that farmers do not earn a lot from subsistence farming.

Agriculture and the Environment in Bangladesh

Depending on the methods employed, agricultural activities may cause severe soil deterioration. Some techniques such as mixed cropping and fallowing does leave room for soil quality to improve over time but practices such as monoculture rapidly depletes the soil of its nutrients. As nutrients in the soil are in fixed supply, having a large number of similar species will focus too deeply on select resources, depleting it quickly and diminishing the health of the system in the process. Evidently, areas where monoculture are practiced, a large inflow of artificially introduced nutrient supply such as fertilizers are required at regular intervals to replenish the lost nutrients.

Agricultural practices also release high amounts of greenhouse gasses and is responsible for around 13% of total global emission. This makes it the second largest emitter after the energy sector. Majority of this emission are in the form of methane and nitrous oxide. The sources of these are cattle belching, burning of crop residue, manure management, etc.

There are further indirect effects of agricultural on the environment too. These effects are mostly from how agriculture is set up. Oftentimes, patches of forest areas are cleared out to free up land for cultivation. This means that the loss of photosynthesizing and oxygen releasing trees must be taken into account as losses in carbon sink. Burning of forest patches also releases carbon dioxide. Excess fertilizers are also potential sources of emission.

In addition to all of these, there are several other environmental problems associated with agriculture. These are:

Deforestation: This results from the lack of land area needed to provide adequate food supply to the local inhabitants. Everybody relies on crops such as rice

and wheat. To cultivate these if adequate land area is not readily available, forest patches are usually cleared to provide space for agricultural practices.

Desertification: This compounds with deforestation. Some ecosystems are highly sensitive to change. When areas are cleared, these land areas lose their balance and their nutrient cycle gets disrupted. With agriculture being done in such areas and with the use of fertilizers and irrigation, the soil health degrades rapidly to a point where it cannot sustain further growth and is unable to support floral diversity. At this point, the land slowly adopts desert like conditions. Furthermore, without an intricate root network to bind the soil together, the soil becomes susceptible to wind erosion.

Soil erosion: This is when the soil becomes loose and is easily removed by forces such as wind or rain. The topsoil holds most of the nutrient, but is also easily disturbed by excessive rainfall or strong wind action. Loss of topsoil results in poorer soil quality which causes a feedback loop that spirals into poorer and poorer soil health.

Overgrazing: This is especially highlighted in the "tragedy of the commons." Having a large number of organisms feeding on a small plot of land removes too much of the grass cover. This loosens up the soil considerably and halts future grass cover growth. The land becomes barren and unproductive as a result.

Water related pollution: Large quantity of water resources are needed to maintain peak crop yield. Depending on the geographic context of the farmlands, river water may not be within reach. Thus, farmers usually resort to using irrigated water. However, this cause salinization which deteriorates soil health.

Also, use of excessive fertilizers leaves an abundance of phosphorus, nitrates, potassium, etc. This, coupled with monoculture, means that not all of the nutrients are used up in the same ratio. Thus, during periods of heavy rainfall, the excess nutrients run off and flow to nearby river networks. The inflow of excessive nutrients causes algal bloom or eutrophication. Eutrophicated river surfaces deprive the bottom of the river from sunlight, which can be deadly for aquatic floral and faunal species.

Effects of Climate Change in Bangladesh Agriculture

In Bangladesh, food security has been one of the major national priorities for last few decades but the target has always been interrupted by the climate change and for resource constraints. Present section of this chapter will highlight the major effects of climate change in the food production and the national resources constraints to address the food security.

However, major constraints in terms of food security in Bangladesh attributed to cultivable land scarcity, irrigation water scarcity in summer, lack of technological knowledge, lack of climate adaptive crop variety, lack of institutions and professionals as well as social and cultural constraints are prominent.

1. Impact of temperature on crop production
2. Impact of rainfall on crop production
3. Impact of sea level rise on crop production
4. Impact of flood on crop production
5. Impact of drought on crop production
6. Land scarcity
7. Irrigation water scarcity
8. Lack of technological knowledge
9. Inadequate institutions and professionals.

In order to mitigate the adverse impacts of climate change on food sector, we need to analyze the possible options that could assist in increasing food security. Therefore, adaptation in the agriculture sector must be well integrated with both the broad national development goals and livelihood priorities at the local level. Rural agrarian people have long been adapted to a variety of climate risks with their traditional knowledge. These coping strategies are varied depending on regions and prevailing socio-economic conditions. As the climate change is a reality now, more and different adaptation intervention is required to ensure food security within a given time.

Formal and informal sources of support can play critical role in minimizing climate risks on food security. The supports may be investments in agriculture and water resources, or may be on infrastructures (e.g., embankments in floodplain and coastal areas to protect against floods and storm surges) or irrigation.

Groundwater irrigation plays an important role in crop agriculture in the drought-prone areas. Irrigation provides a mean to adapt soil moisture condition with diversifying crop agriculture, promoting high-yielding variety crops and increased cropping intensity. Flood-prone areas of the Southern Bangladesh coastal embankment provide protection to crop agriculture and livelihood assets playing a great role in food security. In recent years, government of Bangladesh has invested over USD 10 billion (at constant 2007 prices) for flood management in embankments, coastal polder and cyclone shelters (BCAS, personal communication). With this protection, substantial increases in production have been made possible.

Status of Sustainable Agricultural Systems in Bangladesh

The strides made by Bangladeshi Agriculture in the past four decades have been impressive. Food grain production has increased meeting the food needs of the burgeoning population. However, the main spurt in production has been in irrigated agriculture sector mainly in wheat and rice crops. These are the crops which received the greatest stimulus of varietal improvement, shared major proportion of irrigation and fertilizers and benefited most from governmental price support and procurement policies. In contrast pulses, oilseeds and coarse cereals which are

cultivated mainly in the rain-fed sector remained rather static and deprived of these benefits and are pushed to marginal areas.

Seventy percent of the cultivated area in the country lies in the region of medium to low rainfall (1150 mm and below), and in most cases, the rainfall is inadequate and uncertain with respect to crop water requirements. Higher level of crop production and its stability can be obtained only through irrigation. Till 1951, when the first five-year plan was launched, Bangladesh had an irrigation potential of 22.6 mha. The eight plan target provides for the creation of additional 15 mha potential of which 13.5 mha would be the target for utilization in the terminal year. The expansion of irrigation resources brought about not only enhancement in production but also stability in production.

Nutrient management is the key to higher crop productions. Most of the growth in the food production during the green revolution period is attributed to the higher fertilizer use. The annual fertilizer consumption is expected to rise to about 20 million tons in Bangladesh by the end of this century. This rise in fertilizer use is necessary because we foresee (i) N deficiency will continue to be universal in Bangladeshi soil, (ii) deficiency of P will be next to the order of the extent, (iii) K will become limiting in high-productive regions, (iv) in at least half of the Bangladeshi soils, crops would benefit from Zn treatment and (v) S deficiency will obstruct the optimum productivity in vast majority of Bangladeshi soils. We do not rule out the emergence of additional nutrient disorders, which may stand in the way of sustaining the envisaged growth rate in agricultural productivity. The situation, therefore, calls for an integrated nutrient management and supply system which (i) integrates the use of on-farm generated organic manures with inorganic fertilizers and (ii) exploits the natural nutrients supply through bioengineering and mining of soil resources.

With the advent of the green revolution beginning 1965, the new crop varieties and cropping sequences for intensive agriculture brought to the fore front problems of pests and diseases which caused losses to various crops and their produce. Pesticide consumption has shown a steady increase in Bangladesh. From the mid-fifties, application has increased both in quantity and in coverage. Plant protection coverage increased from 2.4 million hectares in 1956 to 80 million hectares in 1984 and the quantity of pesticides rose from 200 tons in 1955 to 72,000 tons (tech.) in 1987. Their influence in upsetting the ecological balance and polluting the environment is being felt increasingly. Safe use of pesticides should therefore, be the target.

Good-quality seed is one of the basic requirements for augmenting crop production and productivity. The extent of area under high-yielding varieties (HYV) is one of the important indicators of the spread of modern technology for increasing agricultural production. The scope of exploiting the genetic potential of plants for higher yields under different input intensities and under different situations is tremendous. Development of appropriate crop varieties is going to be the main component of sustainable agriculture.

The research strategy for sustainable agriculture should be an exercise in the development of such farming systems which meet the production objectives

through most efficient utilization of inputs without impairing the quality of environment with which the system interacts. Use of land according to its capability, integrated use of purchased inputs and farm residues of production, harnessing maximum productive efficiency from the inputs and from the interacting environments and considering these objectives in long-term perspectives are some of the important aspects of sustainable agriculture strategy.

The need is to integrate the components and evaluate the synthesized systems against the existing system of production. Long-term monitoring of the improved systems with regard to the parameters of sustainability will be required. On-station research could be initiated but the on-farm testing of the developed technology will be required ultimately. The following may be the major course of research work in future on sustainable agriculture in Bangladesh.

- Synthesis of the sub-systems of sustainable agriculture through on-station research
- Evolving a system through synthesis of good production practices for a sustainable farming system based on the location specific needs through on-farm research
- Development of research methods for evaluating the farming systems with regard to its biological, environmental and social efficiency
- Development of methodology for monitoring the improved systems over long period of time.

Issues Related to Gender in Sustainable Agriculture

- Scope of women participation in sustainable agriculture
- The role of women in agriculture is not expressed properly
- Development has neglected women
- Contribution of women to agriculture is not recognized
- Access to agricultural assets. Rights on ownership land/property
- Social attitudes toward women participation
- Low wages for women in agriculture
- Overburdened with work
- No access to appropriate training
- Poverty and its overbearing on women (in agriculture)
- The need for equal participation of men and women for sustainability in agriculture
- Gender bias in agricultural technology generation.

Challenges in Bangladesh Agriculture

The importance on agricultural output cannot be overstated as it forms the carbohydrate source for almost the entire population of Bangladesh, and for people all over the world. However, its environmental impact is also non-negligible. There are many issues associated with agriculture ranging from environmental to societal. A sustainable system for agriculture must work to address these issues. Environmental issues are becoming more evident by the day, with greenhouse gas emission rising and deterioration to soil and water quality getting worse. There are societal issues as well, such as modernization of agricultural practices leading to rising inequality. Richer farmers can afford modern machineries, genetically modified crop seeds and chemical fertilizers. This results in efficient farming, higher yield from a unit plot of land or better utilization of larger farmlands. This not only produces good quality and large quantity of output, but it also means that the produces can be sold at cheaper rates at the local market, or can be processed and exported for higher rates. Farmers who cannot afford such technology are at a disadvantage. With an ever worsening climate, it is difficult to sustain the same amount of yield as they could previously. This issue is compounded with land fragmentation and unsustainable farm practices. With poor quality output and low quantity available to be sold, it becomes difficult to compete with richer farmers, landing them at a competitive disadvantage. This only serves to widen the inequality present.

The aim of sustainable agriculture is to promote production while minimizing environmental impact. However, there are many challenges that needs overcoming in order to achieve this goal. Agricultural area is on the decline at the rate of 1% per annum. However, population growth remains at 1.48% per year. To feed the ever growing population, more farm area is needed. Food shortages might become more apparent as climatic conditions are worsening which means poorer quality output and food shortages are likely. Rapid urban growth also puts a strain on agricultural land as rural areas which are suitable for farming are converted to pavements and concrete surfaces.

There are also many technological challenges that lie ahead, mostly in terms of new innovation and disseminating existing expertise and knowledge. More research is needed in making agricultural output more efficient and less impactful on the environment. Lastly, focus should be directed at restoration of soil quality and fertility.

Conclusion

The fast development of technology for increasing production without giving due importance to the agro ecosystem balance resulted in disturbed biological relationships. The imbalances thus created lead to fast degradation of natural resource

base. Thus, the present productivity levels have become unstable and uneconomic. This necessitated for maintenance of natural resources so as to meet future demand. Thus, the concept of sustainable agriculture emerged.

The sustainable agriculture concept lies in the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the natural resource base and avoiding ecological and environmental degradations.

Sustainable agriculture aims at production of safe and clean food without harming the quality of natural landscapes and with minimal impact on environment. However, it should operate within socially acceptable system and economic viability.

Number of elements right from soil water, biota to agro ecosystems if not judiciously used and maintained may lead to disasters in years to come. Then, they become major factors which can hamper the sustainable agriculture systems.

The backlash of modern agriculture in terms of degradation of natural resource and economical base of farming system compelled to look at low external input supply agricultural systems where in local resources, knowledge, social values are safeguarded with economic viability.

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