UNIT 1 GREEN TO EVERGREEN REVOLUTION

Structure

1.0 INTRODUCTION

For most part of their existence since their origin around 200,000 years ago, *Homo sapiens* and their close cousins *H. neanderthalensis* hunted and gathered food for their survival. Rather suddenly, about 30,000 to 40,000 years ago, the Neanderthals disappeared; there are several hypotheses for their extinction. Before their extinction, there has been gene exchange between *Sapiens* and *Neanderthals* as recent studies suggest. The 'sapiens' with their intelligence and physical capacity initiated settled farming about 10,000 years ago. This consisted of cultivation of a few edible crops and domestication of animals for milk, meat and draught purposes. The earliest farmers were in the region now covered by Iraq, Iran, Jordan, Syria, Turkey, Egypt, Indus river valley and its tributaries in what now constitutes India and Pakistan. The carbon isotope dating suggests that wheat and barley were cultivated in Mesopotamia about 8000 years ago. The data also indicate that sheep, bovines, goats, pigs and asses were domesticated between 6000 and 9000 years ago. Since carbon is integrated into the tissues and bones of all living beings, and its isotope carbon-14 decays with a half-life of 5,600 years, it provides an elegant method to estimate the possible age of organisms that lived a long time ago.

When the humans started settled farming, their population on our planet is estimated to have been between 5 and 10 million. Farming reduced the risk associated with hunting, and gathering, but more importantly provided substantial food security and leisure for creative thinking, music, arts, sculpture, literature etc.The leisure and food security also enhanced human procreation and the human population of the world had increased to 250 million by the arrival of the 1st century of the Christian era. Farming required cutting down trees, and clearing the forests to develop land for cultivation of crops. So, it led to depletion/loss of biodiversity associated with thick forests. Yet, farming at that time did not have chemical fertilizers and pesticides, and was largely in harmony with soil health and other forms of life. The early farmers represented by Roman farmer Varro (1st century A.D) developed strategies to increase productivity through carefully matching crops with appropriate soil types. In fact, Varro had stated, "Agriculture is a science that teaches us what crops should be planted in each kind of soil, and what operations to be carried out, in order that the land may produce the highest yields in perpetuity". Much earlier, the Chinese philosopher Confucius (551-479 B.C) had said "Despite many accomplishments of mankind, we owe our existence to a six-inch layer of top soil and the fact that is rains".

The industrial revolution starting with the invention of steam engine in 1780 by James Watt set in motion developments which improved crop yields, but at the expense of ecological integrity. For example, the invention of nitrogen-containing chemical components for enriching nitrogen content of the soil by Justus Von Liebig in Germany, and the discovery of the insecticidal property of a compound, dichlorodiphenyltrichloroethane (DDT) by Paul Muller. Over the decades, it became evident that both these had adverse ecological effects. Rachel Carson in her book, "Silent spring" (1962), described the harmful effects of chemical pesticides on non-target organisms.

What have been aforementioned become relevant to the following discussion on green revolution and the more recent evergreen revolution. Development of high-yielding varieties using genetic and plant breeding methods are essential for meeting the food requirements of ever-increasing human population, but these exert adverse ecological effects. A consideration of the green and evergreen revolution will clarify that food production and ecology can be reasonably reconciled. These are discussed below.

1.1 OBJECTIVES

After reading this unit, you will be able to:

- define green revolution;
- explain how the green revolution made India self-sufficient in food production; and
- understand the need for evergreen revolution which is designed to fight both the famines of food and rural livelihoods without causing harm to ecology.

1.2 INDIA'S FOOD PRODUCTION AND SELF-SUFFICIENCY: PRE AND POST-GREEN REVOLUTION

Periodic famines of food with millions of starvation deaths were a common feature in the pre-independent, even the pre-British colonial era of India. The famines of Deccan and Gujarat killed about 2 million people during 1600-1632. The population of undivided India then was around 125 million. During the pre-independent British rule (1765-1947), there had been a dozen very major famines killing several millions of people. The Bengal famine of 1943 killed about 2 million people, and epidemics caused deaths of one more million. This indeed was the reason for the first Prime Minister of independent India, late Pandit Jawaharlal Nehru to proclaim, "everything else can wait, but not agriculture". In the absence of any miracle to break the yield ceilings in cereal grain crops, the only avenue to increase the production was to bring more forest land under cultivation. The total area under cultivation went up from 97.32 million hectares in 1950-1951 to 117.84 million hectares in 1962-1963. The percent coverage under irrigation went up from 18.1 percent to 19.8 percent. Production of food grains increased from 50.82 million tonnes to 80.15 million tonnes. With population going up to about 450 million, the question was whether the entire forestland would have to be sacrificed for agricultural production. If so, what would happen to India's rich biodiversity?

Since 1950s, several strategies were being tried to develop high-yielding wheat and rice varieties. In the traditional tall varieties of wheat and rice, the problem with the application of large amounts of fertilizers or manure was that the plants lodged under the weight of their own earheads bearing heavier and greater numbers of grains. So, the logic was to produce dwarf or semi-dwarf crop varieties which can withstand the increased weight at the top (earhead) far better. Then the question was how to develop such tailor-made crop varieties?

In response to that Professor M.S. Swaminathan initiated a variety of experimental approaches to develop dwarf/semi-dwarf wheat varieties. These consisted of (i) hybridization and selection involving cultivated bread wheat and the semi-dwarf, stiff-straw *compactum* and *sphaerococcum* – a subspecies of *Triticum aestivum* with cultivated bread wheats (*T. Vulgare*); (ii) induction of stiff-straw mutants through the use of ionizing radiation and chemical mutagens, (iii) increasing straw stiffness through different chemical treatments. Unfortunately, all the three approaches were unsuccessful because short and stiff straw was always associated with short panicles and consequently, each plant had fewer grains and the yields stagnated at less than one ton per hectare.

Fortunately, nature provided desirable type of "*dwarfing genes*" in a Japanese wheat cultivar "*Norin-10*". The dwarfing had been transferred through conventional plant breeding into Mexican Spring wheat varieties by late Dr. Norman Borlaug. Much credit goes to Professor M.S. Swaminathan who identified the potentials of these in improving wheat yields in India and obtained the seeds (genes) of these Mexican dwarf wheats. By 1967-1968, the dwarf wheats enabled Indian farmers to harvest nearly 17 million tonnes as compared to 12 million tonnes which was the previous highest production recorded in 1964. It was absolutely a remarkable achievement far beyond any one's expectation- wheat yields in the farmers' fields going up from less than 1 ton per ha. to 6.8 to 8.2 tonnes per ha. in 1966-67 national demonstration in Delhi state.

Dr. William S. Gaud, then administrator of the U.S. Agency for International Development coined the term "Green revolution" in 1968 to stress on the sudden spurts in the yields. The word "green" denoted the colour of the green pigment chlorophyll in the leaves where photosynthesis takes place. Photosynthesis is the process in which carbon dioxide and water are converted into starch by utilizing specific wavelength of solar radiation through physical, biophysical, biochemical events in sequence.

The productivity increase is associated with green revolution changed India's image as "*begging bowl*" since 1940s to "*bread basket*". It also established that Paddock brothers (William and Paul Paddock, who in their best seller "*Famine 1975, America's Decision: Who will survive*", had predicted 1975 as the year of doom for India), were wrong. A great cause for humiliation in the book by Paddock brothers was that they had concluded that Indians were too many in numbers to be saved by American food aid, and therefore, America should provide food grains to these countries with lesser and manageable populations who could be saved. Their point was that Indians were multiplying like maggots, since the American food aid would not be able to save all/most of them there was no point in the food aid. The green revolution gained momentum with the finding of dwarfing genes in the Taiwanese rice variety called Dee-gee-woogen. This led to dwarf and semi-dwarf rice varieties with dramatic increases in the *Indica* rices of our country.

1.3 GREEN REVOLUTION: SHORT-TERM GAINS AND LONG-TERM ECOLOGICAL HARM

The dwarf-and semi-dwarf wheat and rice varieties had the capacity to take up as much of chemical nutrients and water from the soil, CO_2 and sunlight from the atmosphere and produce large number of grains. Application of mineral fertilizers and chemical pesticides besides copious irrigation constitutes external inputs. During 1967, Professor M.S. Swaminathan had noted that farmers in the northwestern India tended to apply excessive chemical fertilizers and several repeated applications of chemical pesticides. He also noted that the chemical pesticides led to premature elimination of natural enemies of pests. Hence, in his Presidential Address to the Agricultural Sciences Section of the Indian Science Congress held at Varanasi on 4th January 1968, (several months before William Gaud coined the term **"Green Revolution**" and the government of India commemorated the Wheat Yield Revolution in India by releasing a special stamp in June 1968), Professor M.S. Swaminathan stated: "Exploitive agriculture offers great dangers if performed with only an immediate profit or production motive. The emerging exploitive farming community in India should become ware of this. Intensive cultivation of land without conservation of soil fertility and soil structure would lead, ultimately, to the springing up of deserts. Irrigation without arrangements for drainage would result in soils getting alkaline or saline. Indiscriminate use of pesticides, fungicides, and herbicides could cause adverse changes in biological balance as well as lead to an increase in the incidence of cancer and other diseases, through the toxic residues present in the grains or other edible parts. Unscientific tapping of underground water will lead to the rapid exhaustion of this wonderful capital resource left to us through ages of natural farming. The rapid replacement of numerous locally adapted varieties with one or two high-yielding strains in large contiguous areas would result in the spread of serious diseases capable of wiping out entire crops, as happened before with the Irish potato famine of 1854 and the Bengal rice famine in 1942. Therefore, the initiation of exploitive agriculture without a proper understanding of the various consequences of every one of the changes introduced into traditional agriculture, and without first building up a proper scientific and training base to sustain it, may only lead us, in the long run, into an era of agricultural disaster rather than one of agricultural prosperity".

Unfortunately, these precautionary principles suggested by Professor M.S. Swaminathan, Father of India's green revolution were aside as the focus was on immediate profit. Subsidized electricity to pump out ground water, as also subsidies for chemical fertilizers and pesticides led to the transformation of the "**green**" into a "**greed**" revolution. As expected, the ecological devastation to soil health, fresh water and biodiversity became noticeable in the late 1980s. Yield gains associated with green revolution started showing signs of fatigue. The policy of buying wheat and rice on previously reassured price led the farmers in the green belt area to adopt a wheat-rice rotation without a leguminous grain or fodder deprived the soil of biological nitrogen fixation by bacteria present in the root nodules of legumes. *Sesbania rostrata* introduced from Australia has also stem nodules containing N_2-fixing bacteria. Excessive use of mineral nitrogen and chemical pesticides resulted in the loss of beneficial microbes, and earthworms which pulverize the soil and enrich it with organic matter. Over irrigation, (because of free electricity and availability of plenty of groundwater in the 1960s) without adequate drainage led to progressive salinization of the fertile soil. Several local varieties, excellent for cooking quality and adaptation to local conditions, were replaced with high-yielding dwarf and semi-dwarf varieties. Not being cultivated, these local/traditional varieties were lost, and so were their useful genes. The greed coupled with neglect of ecology destroyed the sustainable benefits of green revolution. It became evident that green revolution rested on three pillars namely high-yielding seeds, good soil fertility, and water management. Its failure is due to mismanagement of soil and water.

The other observation about the green revolution is that it built food security at the national level, but not at the individual household level. The magazines in the late 1980s described the strange paradox of "mountains of grains on one hand, and millions of poor and hungry on the other". The lesson was that green revolution could not provide economic access to food for millions of resource-poor, small farming, fishing and landless rural families. It was ironic that in Asia where the green revolution seeds have contributed to the greatest production success, roughly two-thirds of the undernourished in the entire world live.

There have also been comments that green revolution technology favored the rich and influential farmers than the millions of resource-poor small farmers. More recently, Dhillon and co-workers (2010) have presented data on the productivity decline of wheat and rice in Punjab since 1996-1997. This trend continues unabated.

1.4 FROM GREEN REVOLUTION TO EVERGREEN REVOLUTION

The major lesson learnt from the green revolution is that short term gains in the yield through intensive agronomic practices lead to severe degradation of the ecological foundations of agriculture and jeopardize sustainable productivity. This had been clearly foreseen by Swaminathan (1968). Within the next two decades, Gro Harlem Brundtland (1987, Food 2000: Global Policies for Sustainable Agriculture, Zed Books, London) restated the importance of maintaining the ecological integrity for sustainable productivity. She wrote, "The challenge of increasing food production to keep pace with demand, while retaining the essential ecological integrity of production system, is colossal both in its magnitude and complexity. But we have the knowledge we need to conserve our land and water resources. The application of the concept of sustainable development to the effort to ensure food security requires systematic attention to the renewal of natural resources. It requires a holistic approach focused on ecosystems at national, regional and global levels, with coordinated land use and careful planning of water usage and forest exploitation".

The question then was how to develop an eco-friendly system of agriculture and rural development that would **not** have the drawbacks of the green revolution, and would be conducive for sustainable productivity.

Such a solution was conceived of by Swaminathan (1996) who played a crucial role in ushering in the green revolution in the 1960s. He called it the "evergreen revolution" and its designed goal is to "*achieve productivity in perpetuity without causing ecological harm*". As shown in figure 1, evergreen revolution involves a paradigm shift from a commodity centric to a "systems approach". It involves sustainable management of natural resources and progressive enhancement of soil quality, biodiversity and productivity. The term "evergreen revolution" denotes sustainable advances in crop productivity *per unit of land, water, and time*, without associated ecological harm.

While on the one hand, the ever-green revolution seeks to develop ecofriendly agricultural practices, and on the other hand, strives to ensure food security at the individual level. In contrast, the Green Revolution brought about food security at the national and not at individual level. The ever-green revolution is, therefore, more holistic in ensuring food security at the individual level than the Green Revolution. The experience of India's hunger problem is that millions of people, particularly in the rural and tribal regions, do not have 'access'(i.e., purchasing power which is a function of livelihood for income generation) to food which is available in the markets. Today, India has the dubious distinction of being home to around 300 million hungry people, the largest in numbers anywhere in the world. The reason is that they have no livelihood and hence no money to buy food. Hence, ever-green revolution not only deals with various approaches to eco-friendly cultivation (unit 2) but also sustainable livelihoods (unit 3). It is, therefore, pro-nature and pro-poor. Keeping these in view, Swaminathan (1996) stated that "Sustainable food security involves strengthening the livelihood security of all members within a household by ensuring both physical and economic access to balanced diet, including the needed micronutrients, safe drinking water, environmental sanitation, basic health care and primary education". The rural livelihood security through sustainable management of locally available natural resources and creation of on-farm and non-farm microenterprises with market linkages is thus an essential component of ever-green revolution. And, the on-farm and non-farm livelihoods require technological and knowledge empowerment of the resource-poor, largely illiterate and unskilled marginal farming, fishing and landless communities. The technologies referred to here are the *'ecotechnologies'* which result when the frontier technologies (i.e. biotechnology, information, communication and space technology, nuclear and nano technologies) are blended with traditional knowledge and ecological prudence. Hence, these ecotechnologies acquire a pro-nature, pro-poor and pro-women orientation. The rural women and men forming self-help groups are given training and capacity in ecotechnologies of their choice. The training is imparted by *'techniracy'* (term coined by Professor M.S. Swaminathan in 1972 when he delivered the Princess Leelawati Memorial Lecture, University of Mysore, India) which is a pedagogic method of 'learning by doing'. The rural women and men become eco-micro entrepreneurs with market linkages for their products. Also, microcredit support is facilitated through rural banking system. A village with several eco-micro-enterprises promoting on-farm and non-farm livelihoods for income generation and food security is called a "biovillage" (bios=living). Thus, a biovillage is the site of action of several ecotechnologies. Today, knowledge is power, and the three dimensions of ever-green revolution – viz, the cultivation (ecofriendly methods), consumption (ecoenterprises) and commerce (equity and market linkages) require locale-specific, demand-driven knowledge. The satellite and computer based village knowledge centre provides exactly this.

In conclusion, the transformation of the Green Revolution into an ever-green revolution and the components of the ever-green revolution are depicted as follows:

Evergreen revolution

(Production- gains of today should not erode prospects for the future)

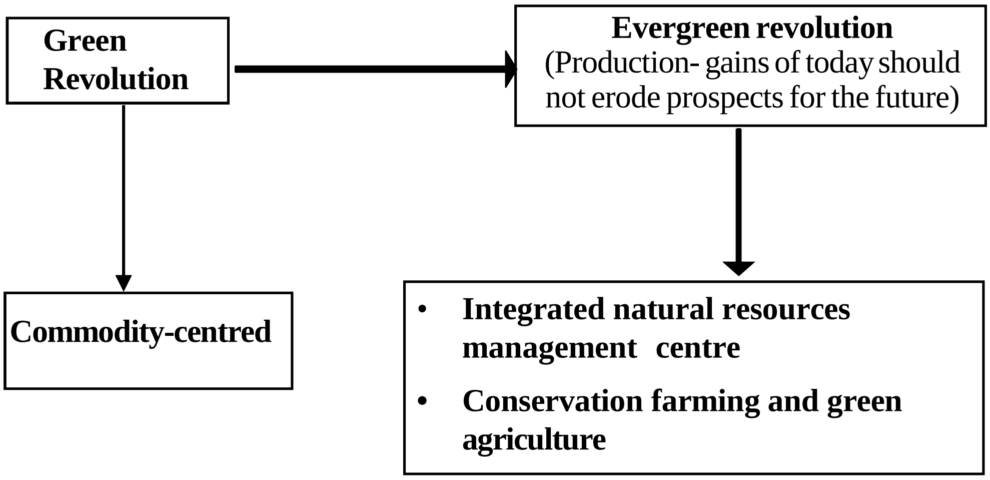

Fig. 1.1: Transforming Green Revolution into ever-green revolution (Paradigm shift) (Kesavan and Swaminathan, 2007)

An urgent question of global dimension is whether ever-green revolution can avert a collision course in which the human beings and the natural world are presently situated. It is recalled that on the eve of the UN conference on Environment and Development held at Rio de Janeiro in June 1992, the Union of concerned scientists (signed by over 1600 scientists including 104 Nobel Laureates drawn from leading scientific academies of 70 countries) published on open letter titled 'World Scientists' Warning to Humanity. In that, they had warned that many of our current practices are leading to serious risk to all the plant and animal (including the humans) kingdoms and therefore, appropriate steps need to be put in place at the earliest. The Scientific American issue of September 2005 was devoted to discussions on 'planet Earth at Crossroads'. Analyses of the plight of our planet Earth in terms "Ecological footprint" reveal how the unsustainable lifestyle and population explosion of the humans have made it exceedingly precarious not just for themselves, but also for all the other forms of life. The "ecological footprint" is a resource management tool that measures how much area of land and water, a human population requires to produce the resources it consumes and to absorb the wastes it generates, under prevailing technology. Every action of the humans impacts the planet's ecosystems. And we depend on the ecological assets to survive. The depletion of the natural resources and the degradation of the environment lead to loss of livelihoods, hunger and misery. As the numbers of consumers (i.e population growth) increase, and/or their lifestyles become extravagant/wasteful, the ecological deficit increases and the nature's capacity to provide basic human needs reduces. The paper entitled, "National natural capital accounting with the ecological footprint concept" by Professor M. Wackernagel et al., in Ecological Economics 29, 375-390 is thought- provoking. In many countries, human populations have already exceeded Earth's ecological capacity. The precipitous rise in atmospheric CO_2 from about 280 ppm around 1780 (when the era of Industrial revolution began) to about 400 ppm in 2010 is also largely related to unsustainable human activities. Today, all life forms on Earth are under the stress of environmental degradation and global warming-related climate change. In this scenario, a transformation of the high levels of fresh water and chemicals inputs based exploitative agriculture into an ever-green revolution is an absolute need of the hour. No wonder, the famous Harvard University biologist, Professor E.O. Wilson has lauded Professor M.S. Swaminathan for proposing an integrated system of agriculture to feed the growing millions of humans without also exerting adverse impact on ecology, and coining the term "ever-green revolution" to describe it. One should read Professor E.O.Wilson's epoch-making book "Future of life", 2002 (Knoff publishing, New York). It is relevant to quote him, "The problem before us is how to feed billions of new mouths over the next several decades and save the rest of life at the same time without being trapped in a Faustian bargain that threatens freedom and security. The benefits must come from an ever-green revolution. The aim of this new thrust is to lift food production well above the level attained by the green revolution of the 1960s, using technology and regulatory policy more advanced and even safer than those now in existence". The word *Faustian* is derived from *Faust* who was a legendary magician and astrologer who sold his soul to the devil in exchange for knowledge and power!

This form of reconciling farming activities with ecological integrity is particularly necessary for the biodiversity-rich developing countries. For instance, India is both population and biodiversity rich with over 110 million farming families with small farms of an average of about 1.5 ha. The ever-green is the best choice for them. In this regard, the statement of Professor M.S. Swaminathan (Swaminathan 1999 'A century of Hope: Towards an era of harmony with nature and freedom from hunger', East-West Books (Madras) Pvt. Ltd) explains the situation in his own words as follows: "What nations with small farms and resource-poor farmers need is the enhancement of productivity in perpetuity, without associated ecological or social harm. The green revolution should become an ever-green revolution rooted in principles of ecology, economics and social and gender equity".

From the foregoing presentation of India's agricultural scenario the centre of which are the degradation of the soil, fresh water and biodiversity and the extreme poverty and hunger of the farmers, it is clear that an attitude of "business as usual" just will not do. There is a vicious spiral between poverty and environmental degradation one accentuating the other. The Green Revolution cannot break this vicious spiral. In this regard, the ever-green revolution is the only option available to achieve productivity in perpetuity, to create on-farm and non-farm livelihoods for millions of small resource-poor farming women and men, to ensure social and gender equity, to prevent degradation of the ecological foundations of basic human needs and to save all other forms of life on Earth. Further, the ever-green revolution has elements that can convert challenges into opportunities. This is so, because it has the power of integration of natural and social sciences and provides for both productivity and livelihoods in millions of small farms. The favored system is *"production by masses"* and growth with equality. The benefit sharing is on the basis of social, economic and gender equity. For a highly populous country with over 700 million people living in about 600,000 villages of India, economic growth should be linked with fighting both the famine of food, and famine of livelihoods. The principles of ever-green revolution are more amenable for harmonious linkage with economic growth than the erstwhile green revolution. From here on, the twin objectives should be to defend the gains of the green revolution, and embark on ever-green revolution.

Finally, what is needed at all levels in the country is a change of mindset from green revolution to ever-green revolution. In addition, the ever-green revolution is technology and knowledge-intensive. The resource-poor, marginal small farm communities should be given access to relevant technologies and locale-specific, demand-driven knowledge. Among other technologies, the **traditiona**l biotechnology (not the r-DNA technology) and modern satellite and computer-based information and communication technology are the major ones in terms of developing *'biological software's* (i.e. biofertilizers, biopesticides, vermicompost etc., for low external input sustainable agriculture (LEISA), and also sustainable management of natural resources for creation of on-farm and non-farm livelihoods. As discussed in the Unit 3, block-2, the biovillages and village knowledge centres are integral components of ever-green revolution.

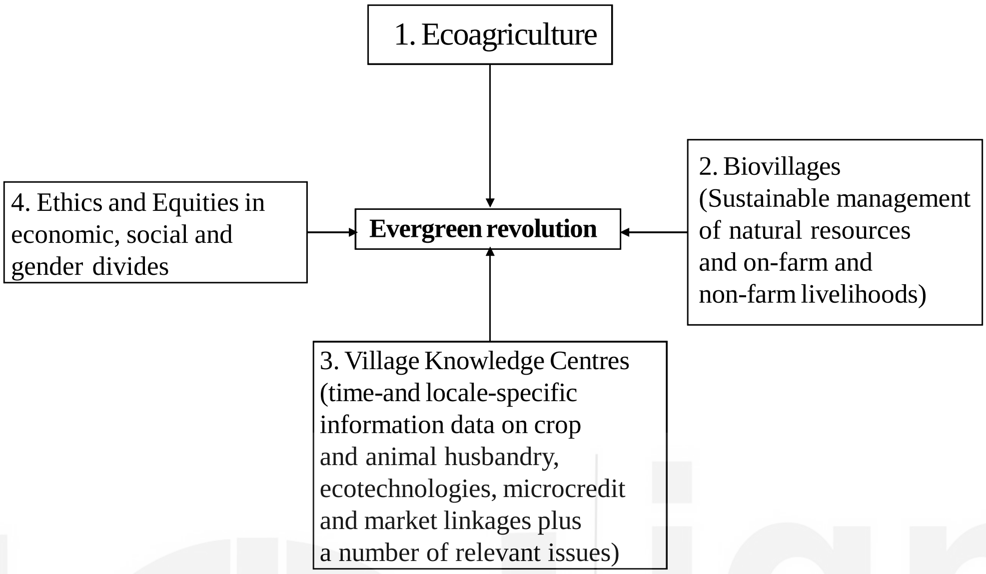

Fig. 1.2: Components of Evergreen Revolution
(Kesavan and Swaminathan, 2007)

Check Your Progress 1

Note: a) Use the space given below for your answer
b) Compare your answers with those given at the end of the unit

1. Define Evergreen Revolution.

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2. What are the components of evergreen revolution?

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1.5 ECOLOGICAL FOUNDATIONS OF EVERGREEN REVOLUTION

The evergreen revolution is not a magic wand with which sustainable rural development and food security could be achieved in a short period. With "ecological footprint overshoot" far in excess of Earth's biocapacity, our planet and out civilization are crossroads. So far as India is concerned, its serious obstacle/ problem of overpopulation is now saddled with accelerated pace of unsustainable lifestyle. There is, of course, worsening poverty and hunger which, as we have noted earlier, form a vicious spiral with environmental degradation. There can be no agenda of accelerated economic growth within the framework of evergreen revolution. This would not please the economic planners who do not appreciate ecological limits to growth, but are addicted Growth Domestic Product (GDP). Often the increase in the GDP reflects the corresponding levels of degradation of the ecological foundations of sustainable agriculture and sustainable rural livelihoods. Chasing after economic growth is not compatible with sustainability. As already pointed out, accelerated economic growth during the last 10-15 years has not reduced, but actually increased the number of hungry people in India. How is this explained? What is the purpose of such accelerated economic growth, which so far has not reduced the number of hungry people, nor would promote conservation of natural resources for the survival of future generations!

The World Summit on Sustainable Development (WSSD) held in 2003 in Johannesburg, South Africa has rightly recognized the essential requirements of water, energy, health, agriculture and biodiversity for sustainable production and provision of the most basic human need, namely food. The term coined at the WSSD to denote these five essential resources is WEHAB. In this context, it is emphasized that accelerated economic growth that pays little attention to the above five items cannot contribute to sustainable food security. On the other hand, evergreen revolution does not aim at making all people rich; what it aims at is to alleviate extreme rural poverty, and ensure food security at individual household level. Hence, it should help in achieving the Millennium Development Goals, particularly the first one, namely to reduce the number of hungry millions by about 50 per cent by 2015.

While the ecological foundation of sustainable agriculture will be dealt with in great detail in the next unit (Pathways to ecoagriculture) in which it is mentioned in brief about sustainable management of soil health, management of crop pests, nutrient management, conservation of rain water, renewable energy and biodiversity conservation. The idea of making reference here to these is that they represent not only a deviation from chemistry-to more biology based inputs with regard to soil, pest and nutrient management, but also a commitment to harvesting and conservation of rainwater, and renewability of energy resources. These are briefly as follows:

i) **Soil health:** Cereal-legume rotation is essential. Stem-modulating legume like Sesbania rostrata is recommended to be grown and ploughed in to enrich soil nitrogen in the range of 100 to 120 kg of N_2 per ha. In addition, Azolla, blue-green algae and other sources of symbiotic and non-symbiotic nitrogen fixation are recommended. Vermiculture composting and organic recycling is essential. A soil health card to monitor the impact of farming systems on the physical, chemical and microbiological components of soil fertility is developed and the farmers are trained to make use of these soil health cards.

ii) **Management of crop pests:** Integrated pest management aims at eliminating all concerns about potential undesirable side-effects of synthetic chemicals. The Integrated Pest Management (IPM) is defined as a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods as compatibly as possible and maintains the pest population levels below those causing economic injury. The consideration of pest population dynamics and thresholds introduced concepts of population ecology, ecosystem science, and economics pest management. Conceptually, IPM operates at the interface of ecological and socioeconomic systems. The IPM is entirely consistent with the principles of ecoagriculture.

iii) **The Integrated Nutrient Management (INM):** From biological aspect of soil fertility management, INM seeks tight nutrient cycling with synchrony between demand of crops and nutrient release within the soil while minimizing loss of nutrients through leaching, runoff, volatilization and immobilization. It is a strategy that incorporates both organic and inorganic plant nutrients to attain higher crop productivity, prevent soil degradation, and thereby help meet the future food supply needs. In the context of promoting the sustainable agriculture, that is an essential component of ever-green revolution, it relies on judicious application of both organic and inorganic nutrients, providing pathways to increase nutrient availability to plants, while minimizing soil degradation.

The INM and IPM require close interaction between scientists with their modern scientific inputs and the traditional farmers with their ecological prudence and practical experience of soil management. Hence, both these require a 'bottom-up' or 'participatory approach'.

iv) **Conservation and Sustainable use of rainwater**: For sustainable agriculture in the predominantly rain-fed regions, the entire rainfall that occurs just in a few days of the year, should be collected, stored judiciously used; every drop of the rainwater is precious. Without equity in sharing, there will be no cooperation in collecting and storing the rainwater. Also, the use of techniques such as drip irrigation should be widely adopted. More sophisticated biotechnology can provide genetic shielding against drought to crop plants with "drought resistance" genes from sturdy species like *Prosopis juliflora*. This involves recombinant DNA technology to transfer "drought-tolerance" genes from Prosopis species to cultivated rice. This is a case of 'genetic adulteration', but could be acceptable in a planet at crossroads.

v) **Renewable energy:** Over the last few decades of the 20^{th} century, farming gradually has become highly energy-intensive. The medium- and large sized farms carry out most of the farm operations (ploughing, planting seeds, and harvesting) with energy-requiring tractors, harvesters and threshers; considerable amount of fossil fuels are utilized, and greenhouse gases are released into the atmosphere. However, when it comes to pumping out ground water for irrigation, both electricity, and diesel are extensively used by millions of small to medium farmers as well. That makes it rather unsustainable. Since energy is an essential input, every effort should be made to harness biogas, biomass, solar, and wind energies to the maximum extent possible. Solar and wind energy could be used in hybrid combinations with biogas, for farm operations like pumping water, drying grains etc.

vi) **Biodiversity Conservation:** It is known that much of the biodiversity, the agro biodiversity in particular, has been traditionally conserved by the forest-dwelling tribal communities, especially the women. Much of their efforts have been for public good at personal cost. Within the framework of the ever-green revolution, steps should be taken to revitalize the genetic conservation traditions of tribal and rural families through social recognition of their contributions and the creation of an economic stake in conservation. Today, India has two Acts, namely, "the protection of Plant varieties and Farmers´ Rights Act – 2001" (PPVFR-2001) and the Biological Diversity Act-2002. These two Acts passed by the Parliament of India were based on the draft proposals developed by Professor M.S. Swaminathan and the M.S. Swaminathan Research Foundation (MSSRF). Besides the provisions for economic stake for the primary conservers, the M.S.S.R.F has also developed a strategy of cultivation-consumption and commercialization for ensuring conservation of the threatened land races, and indigenous varieties of rice, pulses and millets. A system of cultivation along with conservation is the key to ensure that traditional varieties and land races are not totally replaced with a few high yielding varieties. Conserving and enhancing useful genes locked up in low-yielding traditional varieties is as important as going for yield. These traditional varieties are often a source for genes for 'biotic' (pests and diseases) and 'abiotic' (drought, salinity, submergence etc) stresses. The December 26, 2004 tsunami had saturated coastal rice fields with sea water and enhanced the salinity to such high levels that improved rice varieties totally perished. However, a few local traditional varieties remained unaffected and produced low-levels of yield. These obviously have the genes for salinity and submergence tolerance. Our goal of ever-green revolution requires conservation and enhancement of such traditional varieties.

MSSRF's Gene-seed-grain-water banks

The M.S. Swaminathan Research Foundation has also developed Community-Centred Gene-Seed-Grain-Water banks with a view to link livelihood security of the farmer-conservers with ecological security. This is mainly to help the rural and tribal women and men who have been largely responsible for in-situ on-farm conservation of landraces. The on-farm conservation by rural and tribal communities (see the community conservation section in Figure 3) does not receive public or private funding or any recognition and reward. However, from the point of sustainable agriculture, this section of conservation is very important. In order to strengthen this neglected component in the conservation chain, MSSRF has developed a model of ex-situ community gene bank and in-situ on-farm conservation. The ex-situ community gene bank is unique in the sense that the accessions are developed by the rural and tribal farming families. They had evolved and conserved these accessions and deposited them in a medium-term storage facility maintained at 4°C and 25 percent Relative Humidity (Community Gene Bank) by the MSSRF at Chennai. MSSRF is also the trustee for these accessions. A duplicate sample of each accession is also stored in the long-term cold storage at the National Gene Bank as additional safeguard. The accessions in the Community Gene Bank at the MSSRF are also conserved in-situ on-farm by the tribal and rural families.

The in situ on-farm conservation provides fresh seeds with higher percentage of germination after each growing season, and also allows the natural evolutionary processes to go on. Another important dimension of the in situ on-farm, conservation is the opportunity for 'participatory breeding' involving the farmer-conservers and the expert plant breeders. That brings modern scientific know-how and the traditional knowledge together in evolving locale-specific crop varieties.

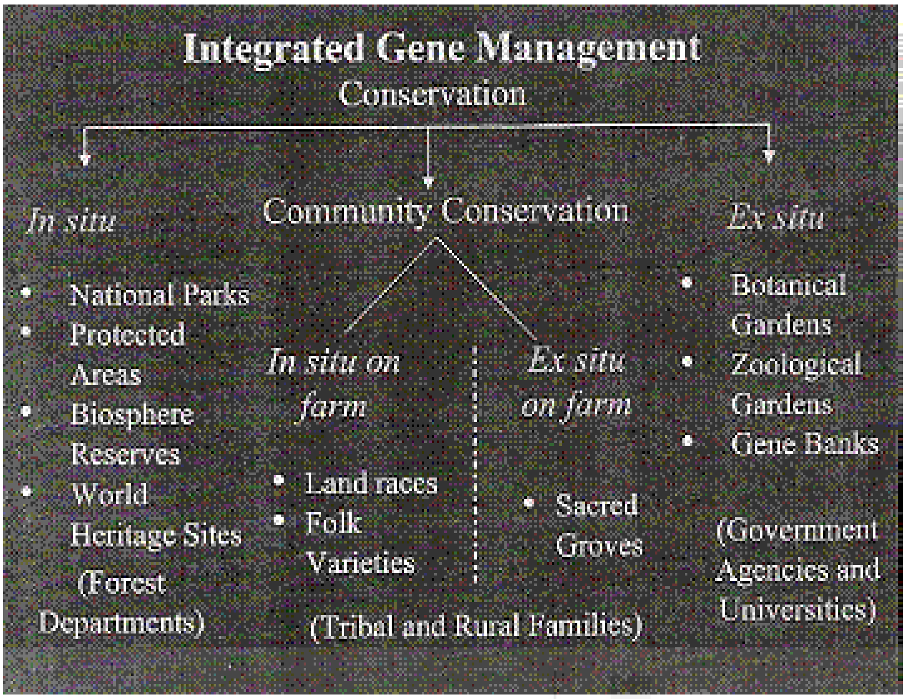

Fig. 1.3: Integrated Gene Management

One of the aspects of the ever-green revolution is to link conservation, cultivation and consumption in a mutually reinforcing manner. For this, it will be useful to foster the establishment of community gene, seed, water and grain banks in all the villages. It is as follows:

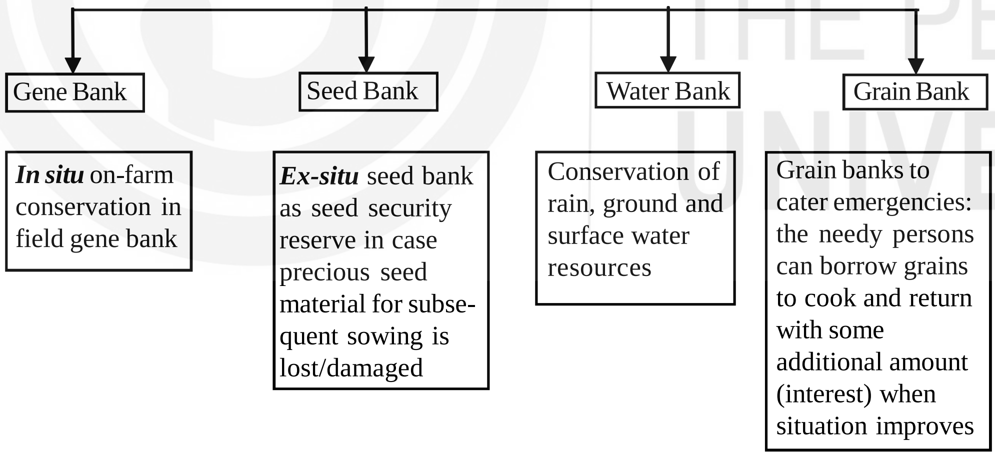

Fig. 1.4: Community Gene-Seed-Water-Grain Bank System

Check Your Progress 2

Note: a) Use the space given below for your answer

b) Compare your answers with those given at the end of the unit

1. Describe how the integrated nutrient management enhances the soil fertility?

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....

....

2. Define Ecological foot Print.

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1.6 LET US SUM UP

- The productivity increase associated with green revolution changed India's image as "begging bowl" since 1940s to "bread basket". The major lesson learnt from the green revolution is that short term gains in the yield through intensive agronomic practices lead to severe degradation of the ecological foundations of agriculture and jeopardize sustainable productivity. It could not provide economic access to food for millions of resource-poor, small farming, fishing and landless rural families.
- The basic observation about the green revolution is that it built food security at the national level, but not at the individual household level.
- The term "evergreen revolution" denotes sustainable advances in crop productivity per unit of land, water, and time, without associated ecological harm. It involves a paradigm shift from a commodity centric to a "systems approach".
- The rural livelihood security through sustainable management of locally available natural resources and creation of on-farm and non-farm microenterprises with market linkages is thus an essential component of ever-green revolution. And, the on-farm and non-farm livelihoods require technological and knowledge empowerment of the resource-poor, largely illiterate and unskilled marginal farming, fishing and landless communities.
- Evergreen Revolution addresses
  - o the ecological foundations (soil health, biodiversity, water, renewable energy) of agriculture,
  - o conservation and enhancement of biodiversity in general, and the agrobiodiversity in particular,
  - o linking livelihood security with ecological security,
  - o a "bottom-up" participatory approach in achieving productivity in perpetuity without ecological harm,
  - o Community-centred approaches for conservation and sustainable use of Natural resources especially water with social and gender equity and
  - o Finally, technological and knowledge empowerment of the resource-poor, largely illiterate, and unskilled rural women and men to embark on a path of sustainable livelihoods.

1.7 KEY WORDS

Ever-green Revolution: Achieving productivity in perpetuity without causing ecological harm

Integrated Pest Management: A pest management system that utilizes all suitable techniques and methods as compatibly as possible and maintains the pest population levels below those causing economic injury.

Integrated Nutrient Management: A strategy that incorporates both organic and inorganic plant nutrients to attain higher crop productivity, prevent soil degradation, etc.

1.8 REFERENCES AND FURTHER SUGGESTED READINGS

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1.9 KEY TO CHECK YOUR PROGRESS

Check Your Progress 1

1. Your answer must include the following points
   - Productivity in perpetuity, without associated ecological or social harm
2. Your answer must include the following points
   - Ecoagriculture
   - Biovillages
   - Village Knowledge centres
   - Ethics and equities in economics, social and gender divides

Check Your Progress 2

1. Your answer must include the following points
   - INM requires nutrient cycling with synchrony between demand of crops

and nutrient release within the soil while minimizing loss of nutrients through leaching, runoff, volatilization and immobilization.

- It is a strategy that incorporates both organic and inorganic plant nutrients to attain higher crop productivity, prevent soil degradation, and thereby help meet the future food supply needs.
- It relies on judicious application of both organic and inorganic nutrients, providing pathways to increase nutrient availability to plants, while minimizing soil degradation.
- The INM also require close interaction between scientists with their modern scientific inputs and the traditional farmers with their ecological prudence and practical experience of soil management by 'bottom-up' or 'participatory approach'.

2. Your answer must include the following points

- The ecological footprint is a resource management tool that measures how much area of land and water, a human population requires to produce the resources it consumes and to absorb the wastes it generates, under prevailing technology.
- Every action of the humans impacts the planet's ecosystems.