Training Manual on

INTEGRATED FARMING SYSTEM FOR SUSTAINABLE HILL AGRICULTURE: AN OPTION FOR CLIMATE SMART AGRICULTURE & NATURAL RESOURCE MANAGEMENT

Edited By -


ICAR Research Complex for NEH Region
Manipur Centre, Imphal
Training Manual

INTEGRATED FARMING SYSTEM FOR SUSTAINABLE HILL AGRICULTURE: AN OPTION FOR CLIMATE SMART AGRICULTURE AND NRM

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PREFACE

Sustainable development on our planet cannot be achieved without a major contribution from agriculture. People must be fed, and agriculture has to face the challenge of producing sufficient food for a rapidly growing world population whilst maintaining the world’s fragile resources. Modern farming systems have evolved to meet this need in a way that combines the essential requirements of profitability and productivity. Sustainable development must encompass food production alongside conservation of finite resources and protection of the natural environment so that the needs of people living today can be met without compromising the ability of future generations to meet their own needs. Economic and ecological access to food could be only ensured by adopting farming system approach consisting of change from commodity-based to resource-based planning and integrated use and management of land, water and human resources to maximize income and employment. The primary goals of farming system is to maximize the yield of all component to provide study and stable income at higher level, rejuvenation of systems productivity and achieve agro-ecological equilibrium. Biotech stress management through natural cropping systems management and reducing the use of fertilizers and other harmful agro-chemicals to provide pollution free, healthy produce and environment to the society. The Training Manual on "Integrated Farming System for Sustainable Hill Agriculture : An Option for Climate Smart Agriculture and Natural Resource Management" deals with various aspects of integrated farming system in a holistic way.

We hope that this Training Manual will be a valuable source of information for scientists, teachers, extension functionaries, students, progressive farmers and policy planners of our country.

Editors
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The human population of India has increased to 1210.2 million at a growth rate of 1.76 per cent in 2011 and is estimated to increase further to 1530 million by 2030. There are projections that demand for food grains would increase from 250 million tonnes to 345 million tonnes in 2030. The Indian economy is predominantly rural and agricultural, and the declining trend in size of land holding poses a serious challenge to the sustainability and profitability of farming. In view of the decline in per capita availability of land from 0.5 ha in 1950-51 to 0.15 ha by the turn of the century and a projected further decline to less than 0.1 ha by 2020, it is imperative to develop strategies and agricultural technologies that enable adequate employment and income generation, especially for small and marginal farmers who constitute more than 80% of the farming community.

To meet the multiple objectives of poverty reduction, food security, competitiveness and sustainability, several researchers have recommended the farming systems approach to research and development. A farming system is the result of complex interactions among a number of inter-dependent components, where an individual farmer allocates certain quantities and qualities of four factors of production, namely land, labour, capital and management to which he has access (Mahapatra, 1994). This is a multidisciplinary whole-farm approach and very effective in solving the problems of small and marginal farmers. The approach aims at increasing income and employment from small-holdings by integrating various farm enterprises and recycling crop residues and by-products within the farm itself (Behera and Mahapatra, 1999; Singh et al., 2006). No single farm enterprise is likely to be able to sustain the small and marginal farmers without resorting to integrated farming systems (IFS) for the generation of adequate income and gainful employment year round (Mahapatra, 1992; 1994). Farming systems approach, therefore, is a valuable approach to addressing the problems of sustainable economic growth for farming communities in India. The basic aim of integrated farming system (IFS) is to derive a set of resource development and utilization practices, which lead to substantial and sustained increase in agricultural production (Kumar and Jain, 2005). Integrated farming systems are often less risky, if managed efficiently, they benefit from synergisms among enterprises, diversity in produce, and environmental soundness (Lightfoot, 1990). On this basis, IFS models have been suggested by several workers for the development of small and marginal farms across the country (Rangaswamy et al., 1996; Behera and Mahapatra, 1999; Singh et al., 2006).
Climate Change and Food Security Scenario in Manipur

Climate change is a reality and Manipur state has also been affected due to changing climatic scenario. Trend analysis of weather variables of Imphal region under National Initiative on Climate Resilient Agriculture (NICRA) revealed that the mean annual maximum temperature (1954-2014) has shown increasing trend (0.1°C per decade). The mean annual minimum temperature has also increased significantly (3°C per decade). The total annual rainfall recorded during the period from 1954 to 2014 showed increasing trend (23.5 mm per decade); however, decreasing trend has been observed in February, June, July and November (-10.8 to -0.1 mm per decade). The mean annual rainy days (1954-2013) has shown increasing trend. Decreasing trend in total monthly rainy days has been observed in January, February, April, June and July. The mean annual maximum relative humidity (RH) increased significantly (3.8% per decade) during the period from 1985-2013; whereas, the mean annual minimum RH (1985-2013) shown a decreasing trend (-1.6% per decade). The mean monthly maximum RH has shown significantly increasing trend (3.0 to 5.6% per decade) throughout the year. Similarly, decreasing trend has been observed in mean monthly minimum RH (-3.2 to -0.6% per decade) in all months except May (1% per decade). The trend of annual temperature and rainfall in Imphal region are presented in Figure 1 and 2 (ICAR Research Complex for NEH Region Region, Manipur Centre, 2015).

The state is projected to experience an increase in temperature above 1.7°C (Manipur State Action Plan on Climate Change, Directorate of Environment, Government of Manipur, 2013). The projected increase in annual average temperatures for the southern districts are higher than the northern districts. The entire state of Manipur is projected to receive increased precipitation. The northern parts of the state are projected to experience an increase of ≥ 19% of rainfall. This roughly correlates with observed trends over the last 30 years. The districts of Tamenglong and Senapati are projected to experience an increase in precipitation of ≥21%; whereas, the southern districts also experience an increase in precipitation of ≥15%. Further, an increase in the number of extreme rainfall (100 mm/day) conditions is projected for the state. Crop yields are projected to decrease by 10% in 2030.

According to Jamir and De (2013), an increasing trend has been observed in green house gas emission in Manipur from 1980 to 2005 in terms of CO$_2$ (2274 Gg/year rate of increase with 3.85% compound growth rate), CH$_4$ (0.419 Gg/year rate of increase with 0.85% CGR) and N$_2$O (0.008 Gg/year rate of increase with 8.49% CGR).

Hence, a high inter-annual variability in crop yields are projected due to increased frequency of extreme precipitation events. Incidence of pest and diseases as well as soil erosion with degradation is projected to increase. Increase in evaporation and runoff is projected which will decrease the soil moisture recharge. There is also a projection of scarcity of fresh drinking water. Upward movement of plant species is projected with rise in surface temperatures. Decreased microbial population is projected with increasing altitudes and loss of vegetation will pose potential threat for soil erosion. There is
projection about loss of bio-diversity and extinction of rare/threaten flora and fauna. The projected food grain production of the state in 2050 has been estimated to be 77105 thousand tonnes; whereas the requirement will be 79323 thousand tonnes. Hence, the state will be in deficit of 2218 thousand tonnes food grain in 2050 (Vision 2050. ICAR Research Complex for NEH Region, Umiam, Meghalaya).

The state has abundant natural resources viz., soil, water, forest etc. The Environmental Sustainability Index (ESI) of Manipur is very high (100.00) and it ranked 2 among the Indian states during 2011 (Byravan and Chella, 2012). Loktak lake which is the largest freshwater lake (230 sq. km. surface area) in North East India is located in Manipur. There are four major river basins in Manipur State namely the Barak River Basin (9041 sq km catchment area) to the west, the Manipur River Basin (6332 sq km catchment area) in central Manipur, the Yu River Basin in the east, and a portion of the Linyi River Basin in the north. The total water body in the state covers an approximately 56.46 thousand hectares. However, the hydrological system has been drastically changed due to climate change and human pressure.

An area of 1699 thousand hectares in the state is under forest cover (Indian State of Forest Report 2013). There are seven types of forest class found in Manipur viz., Tropical semi-evergreen forest, Moist deciduous forests, East Himalayan Wet temperate forests, Sub-Alpine Forests, Grassy blanks, Bamboo brakes and Cane brakes (Annual Administrative Report, Department of Forest, Government of Manipur 2010-11). However, the state is very vulnerable to soil erosion due to its undulating topography, steep slope and high rainfall. Approximately 2190 thousand hectares area in the state has been classified as eroded area. Deforestation and practice of jhum cultivation accelerated the erosion problem. It was reported that an about 1189 thousand hectares area of the state comes under different soil loss classes under water erosion (>10 t/ha/year), 2232 thousand hectares area comes under degraded and wasteland category and 1597 thousand hectares area is affected by soil acidity (ICAR and NAAS, 2010).

**Genetic agro-biodiversity in Manipur**

Manipur comes under one of the mega biodiversity hotspots in the world. The state is a treasure trove of various flora and fauna. It consists of a large variety of plants, ranging from short and tall grasses, bamboos and trees of various species. The hilly terrain is occupied by medium to thick tropical deciduous forests, and ground is covered with thick undergrowth of bushes, shrubs, tall grasses and other types of mixed vegetation. Bamboo forests are common in the state with luxuriant growth in the lower and gentle hill slopes. Out of 126 taxa of bamboos reported from India over 53 species are from Manipur.

Manipur has a rich genepool of primitive cultivars and land races of various agri-horticultural crops. There are enormous genepool of rice (more than 269 local varieties and land races), maize, cucurbits, legumes, tuber crops, turmeric, ginger and chilli. The state is graced with many underutilized fruits and vegetable crops, medicinal plants and flowering plants especially orchids. Many epiphytic and terrestrial orchids of immense
horticultural value are grown in wild. More than 500 varieties covering 249 species belonging to 69 genera of the family Orchidaceae have been reported from this state. Shirui lily (Lilium mackliniae) is a rare Indian species of terrestrial lily which is found only in the upper reaches of the Shirui hill in Ukhrul district.

The wealth of medicinal plants is an important asset in the flora of a state. As many as 1200 species of medicinal plants and the local medicinal uses of about 430 species have been documented. There are also numerous wild relatives of cultivated plants. Mention may be made of Alpinia, Alocasia, Amomum, Mucuna, Pyrus, Prunus and Rubus etc. Wild species of banana like Ensete glaucum, Musa cheesmanii, M. magnesium, M. balbisiana etc. have been recorded from this state. The genus Citrus is represented by Citrus reticulata, C. jambhiri, C. macropertha, C. indica, C. latipes, C. maxima, C. medica and other species etc. Fiber crops like Bauhinia, Butea, Cannabis, Corchorus, Crotalaria, Sesania, Side and their varieties are common in this state. Among the forest trees Laurus, Melia, Bauhinia, Dillenia, Lagerstroemia, Terminalia, Gmelina, Bombax, Michelia, Schima, Gmelina, Podocarpus, Tectona, Dipterocarpus, Melanorrhoea, Quercus, Magnolia, Acer, Prunus, Pyrus, Ligustrum, Taxus, Bucklandia, Castanopsis are commonly found in Manipur. Over 20 species gymnosperm and more than 300 species of Pteridophytes flora have been reported from Manipur. Different species of mushroom are also found in forest areas. The state also has a record of existence of more than 121 algae, 50 species of fleshy fungi and a few Moses. According to India Biodiversity Portal, out of 75 endemic plants of Manipur, 27 native plants have been classified as rare, endangered and threatened species.

About 31 endemic mammals have been reported from the state. Of this, 20 mammals comes under rare and endangered class. Cattle, buffalo, sheep, goat, pig and dog are the major livestock enterprises in Manipur. The state is also known for indigenous breed of horse and pony. Regarding avian fauna, approximately 73 different types of bird including 10 rare and endangered birds are found in the state. The state is also a home for 8 species of silkworm. Manipur has more than 200 fish species and 139 ornamental fish species. Of these, 30 species are of vulnerable category, 15 species are endangered and 3 species are critically endangered. Indigenous fishes like Bangana dero, Semiplotus manipurensis, Garra manipurensis, Osteobrama belangeri, Puntius manipurensis, Parambasis waikhomi, Lepidocephalichthys irrorata, Pangio pangia, Mystus ngasep and Glyptothorax manipurensis etc. are the few important members of the fishery wealth of Manipur.

Even though scientific and sustainable management of biodiversity resources has become one of the prime issues in Manipur, there is a wide gap pertaining to biodiversity management and conservation. As a result, many floral and faunal wealth of the state are now at the verge of extinction.

Source : ENVIS Centre: Manipur Status of Environment and Related Issues, Directorate of Environment, Govt. of Manipur. (http://www.manenvis.nic.in/)
Farming System (FS)

Farming is a process of harnessing solar energy in the form of economic plant & animal products; whereas, system implies a set of interrelated process organized into a functional entity. Hence, a farming system is defined as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. Depending on the scale of the analysis, a farming system can encompass a few dozen or many millions of households. Farming systems of a region are decided by and large, by a number of soil and climatic parameters which determine overall agro-ecological setting for nourishment and appropriateness of crops and livestock or set of agriculture enterprise. At farmers’ level, potential productivity and monetary benefits act as guiding principles while opting for a particular farming system. The decisions w.r.t. choice of farming systems are further narrowed down under influence of several other forces related to infrastructure facilities, socio-economic factors and technological developments, all operating interactively at micro-level. The household, its resources and the resource flows and interactions at the individual farm levels are together referred to as a farm system (FAO, 2001). Systems could be defined as an organised unitary whole composed of two or more inter dependant and interacting parts, components or subsystems delineated by identifiable boundary or its environmental super system. It is a set of interrelated elements each of which is associated directly or indirectly with other elements and no subset is under-related to any other subsets. In system approach, the whole farms rather than the individual crops/enterprises is considered before any decision relation to the choice of enterprise and or technology is made. The farming systems can also be described and understood as by its structure and functioning. The structure in its wider sense includes among others, the land use pattern, production relations, land tenures, size of holding and their distribution, irrigation, marketing including transport and storage, credit institutions and financial markets and research and education.

Farming system designates a set of agricultural activities organized into functional units:

- To profitably harness solar energy
- Preserving land productivity
- Ensuring environmental quality
- Maintaining desirable level of biological diversity and ecological stability.

Resource Management strategies achieving economy and sustaining agriculture production

- Meeting diverse requirements of farming house holds
- Conserving the resource base and maintaining environment quality
- Efficient use of land, labour and available resources

Therefore, farming system is a complex inter-related matrix of soil, plants, animals, implements, power, labour, capital and other inputs controlled in parts by farming
families and influenced to varying degrees by political, economic, institutional and social forces that operate at many levels (Mahapatra, 1992).

**Factors determining type of farming**

- Physical factor (Climate, soil, topography)
- Economic factor (Marketing cost, labour availability, capital, land value, competition for enterprises, consumer demand, prevalent pest and diseases)
- Social factor (Type of community, easy transport, marketing facilities and co-operative spirit)
- Objective (Income, production, minimizing cost etc.)
- Availability of resources and components

Farming system focuses on the interdependencies between components under the control of household and how these components interact with the physical, biological and socio-economic factors, which is not under the control of household. Farm household is the basic unit of farming system and interdependent farming enterprises carried out on the farm. Farmers are subjected to many socio-economic, bio-physical, institutional, administrative and technological constraints. The operator of the farming system is farmer or the farming family. The highly simplified model of farming system puts the farmer the decision maker, at the center. Decisions are influenced by the priorities of the household, farmer’s knowledge and experiences, and resource at his command. External factors - natural, economic and sociocultural, also plays significant roles.

**Rainfed Farming Systems (RFS)**

Rainfed agriculture occupies 68% of India’s cultivated area and supports 40% of the human and 60% of the livestock population. It produces 445 of the food requirement, thus has and will continue to play a critical role in India’s food security. Agriculture in the rainfed areas and fragile ecosystems is inevitable for meeting the food, fibre and energy needs of the local inhabitants. If the rainfall is adequate, farmers can expect a bumper crop. In case of less rainfall, crop may fail and it may be lost completely if rainfall is low (draught). On the other side, a heavy rainfall may results in uncertainty in crop production and it may lose or survive depending on the severity of flood. However, aberrant behaviour of monsoon rainfall, eroded and degraded soils with multiple nutrient and water deficiencies, declining ground water table and poor resource base of the farmers are principle constraints for low and unstable yields in rainfed areas (Singh et al, 2004). The guiding principles for selection of crops and varieties for efficient management of resources in rainfed areas are land use capability concept, water availability concept, crop substitution, quantity and distribution of rainfall, soil depth and performance of crops. Effective growing period concept is mostly used in deciding cropping systems in different agro-climatic zones. Traditionally rainfed farmers are small
subsistent land holders integrating livestock with crop production. With continuing population growth, intensifying crop and livestock systems continue to play vital role in maintaining rural livelihoods. The philosophy behind shifting from cropping system to the farming system mode involves (i) in situ recycling of organic residues including farm wastes generated at the farm to reduce the dependency on chemicals (ii) decrease in cost of cultivation through enhance input use efficiency, (iii) effective use of by-products/wastes of one component for the benefit of other component/components (iv) upgrading of soil and water quality and bio-diversity, (v) increased water productivity, (vi) nutritional security through minimizing chemical residues in soil plant animal human chain, and (vii) environmental security by moderating flow of green house gases from the soil to environment. Farming system provides a vast canvass of livelihood gathering, a better risk coping strategy, continuous flow of income and employment throughout the year for small landholders. It involves utilization of primary and secondary produce of one system as a basic input of other system through making them mutually integrated. In kharif season, the rainfall both in terms of quantum and distribution decides the effective growing season and it becomes critical in selecting cropping systems for a given reason. In rabi season available moisture in soil profile at sowing time dictates the choice of crops in a given cropping system. In regions, receiving 350-600 mm of rainfall and 20 weeks effective growing season, intercropping (150% cropping intensity) is possible in regions having 20-30 weeks of effective growing season from 650-750 mm of rainfall. In areas receiving more than 750 mm of rainfall and having an effective growing season of more than 30 weeks double cropping is assured (Singh and Subba Reddy, 1986). Early planting and harvesting at physiological maturity of crops, less number of tillage operations, deep placement of fertilizers for rabi crops are crucial for succeeding double cropping.

Farming Systems Research (FSR)
The farming system research activities are to be farmer oriented, system oriented, problem solving approach, inter-disciplinary, compliments mainstream disciplinary research, test the technology in on-farm trials and provides feedback from the farmers. The strategy of FSR should emphasize that the research agenda should be determined by explicitly define farmers needs through an understanding of the existing farming systems rather than its perception by the researchers. The farming systems research and extension should be dealt in holistic manner on farmers participatory mode with problem solving approach, keeping genders activity, interdisciplinary and interactive approach. It should emphasize extensive on-farm activities and complement the experimental on-station research and acknowledges the location specificity of technical solutions and document the inter dependencies among multiple clients. Greater importance is placed on feedback to modify the content of subsequent on farm trials, if necessary, by changing research priorities focusing policy shifts based upon micro level analysis. Hence farming systems research is designed to understand farmers’ priorities, strategies and resource allocation decisions.
The core characteristics of the farming system research can be described as follows.

**It is problem solving:** As an applied problem solving approach, it emphasizes on developing and transferring appropriate technologies to overcome production constraints through diagnosis of biophysical, socio-economic and institutional constraints that influence technological solutions.

**It is holistic:** The whole farm is viewed as a system encompassing interacting sub-systems, and no potential enterprise is considered in isolation.

**It acknowledges the location specificity of technological solutions:** Recognizing the location specific nature of agricultural production problems, it emphasizes on testing and adaptation of technological solutions based on agro-ecological and socio-economic specificities.

**It defines specific client groups:** Emphasis is made on the identification of specific and relatively homogeneous groups of farmers with similar problems and circumstances for whom technology is to be developed as the specific client groups. On the basis of common environmental parameters, production patterns and management practices, relatively homogeneous recommendation domains need to be identified.

**It is farmer participatory:** It revolves around the basic principle that successful agricultural research and development efforts should start and end with the farmers. Farmer participation is ensured at different stages of technology generation and transfer processes such as system description, problem diagnosis, design and implementation of on-farm trials, and providing feedback through monitoring and evaluation.

**It gives weightage to ITK system:** The Indigenous Technical Knowledge (ITK), which is time tested at the farmer’s level for sustainability through a dynamic process of integrating new innovations into the system as they arise, has to be properly understood by the scientists and utilised in their research activities.

**It is concerned with ‘Bottom-up’ research strategy:** It begins with an understanding of existing farming system and the identification of key production constraints.

**It is interdisciplinary:** It lays greater emphasis on interdisciplinary cooperation among the scientists from different areas of specialisation to solve agricultural problems that are of concern to farmers.

**It emphasizes extensive on-farm activities:** It involves problem analysis through diagnostic surveys, on-farm testing of the developed technologies, and providing feedback through evaluation to influence the research agenda of the experiment stations. It provides a structural framework for the farmers to express their preferences and apply their evaluation criteria for selecting technologies suiting to their circumstances.
It is gender sensitive: While explicitly acknowledging the gender-differentiated roles of farm family in agriculture, it emphasizes the critical review of farming systems in terms of activities analysis, access and control over resources and benefits and implication's in developing relevant research agenda.

It is iterative: Instead of trying to know everything about a system at a time, it requires step-by-step analysis of only key functional relationships.

It is dynamic: It involves recurrent analysis of the farming systems, permitting continuous learning and adaptations.

It recognizes interdependencies among multiple clients: The generation, dissemination and adoption of relevant technologies to improve the productivity and sustainability of agriculture require productive and interactive linkages among the policy planners, scientists, developmental agencies and farmers. The approach attaches more importance for this critical factor.

It focuses on actual adoption: It is to be judged by the extent to which it influences the production of socially desirable technologies that diffuse quickly amongst specified groups of farmer clients.

It focuses on sustainability: It seeks to harness the strengths of the existing farming practices, and to ensure that productivity gains are environmentally acceptable. Towards preserving the natural resource base and strengthening the agricultural production base, it attempts to develop technologies that are environment friendly and economically viable.

It complements experiment station research: It only complements but does not substitute on station research. It has to draw upon the scientific knowledge and technologies generated at research stations. It has to be kept in mind that the approach is not being promoted as panacea for all maladies of local agricultural production systems.

Integrated Farming System (IFS)

Integrated farming system is the scientific integration of different interdependent and interacting farm enterprises for the efficient use of land, labour and other resources of a farm family which provide year round income to the farmers specially located in the handicapped zone. IFS a component of farming system research (FSR), introduces a change in farming techniques for maximum production is a cropping pattern and take care of optimal utilization of resources. Unlike specialized farming system (SFS) integrated farming systems activity is focused round a few selected, inter-dependent, inter-related and often inter-linking production systems based on few crops, animals and related subsidiary professions. Integrated farming system involves the utilization of primary produce and secondary produce of one system as basic input of other system, thus making the mutually integrated as one whole unit. There is a need to effective
linkages and complementarities of various components to develop holistic farming system. Integrated farming is defined as biologically integrated system, which integrates natural resources in a regulation mechanisms into farming activities to achieve maximum replacement of off-farm inputs, secures sustainable production of high quality food and other products through ecologically preferred technologies, sustain farm income, eliminates or reduces sources of present environment pollutions generated by agriculture and sustains the multiple function of agriculture. It emphasizes a holistic approach. Such an approach is essential because agriculture has a vital role to play that is much wider than the production of crops, including providing diverse, attractive landscapes and encouraging bio-diversity and conserving wild life. Sustainable development in agriculture must include integrated farming system with efficient soil, water crop and pest management practices, which are environmentally friendly and cost effective. The future agricultural system should be reoriented from the single commodity system to food diversification approach for sustaining food production and income. Integrated farming systems, therefore, assume greater importance for sound management of farm resources to enhance farm productivity, which will reduce environment degradation and improve the quality of life of resource poor farmers and to maintain agricultural sustainability. The difference between mixed farming and integrated farming is that enterprises in the integrated farming systems interact eco-biologically, in space and time, are mutually supportive and depend on each other. Hence, integrated farming system is also known as ‘Integrated Biosystems’.

The aims of the integrated farming system can be achieved by efficient recycling of farm and animal wastes, minimizing the nutrient losses and maximizing the nutrient use efficiency, following efficient cropping systems and crop rotations and complementary combination of farm enterprises. The various enterprises that could be included in the farming system are crops, livestock, poultry, fishery, sericulture, agro-forestry, horticulture, mushroom cultivation, apiary, crop residue recycling etc. Thus it deals with whole farm approach to minimize risk and increase the production and profit with better utilization of wastes and residues. Integrated farming system is based on the concept that “there is no waste”, and “waste is only a misplace resource which can become a valuable material for another product. It may be possible to reach the same level of yield with proportionately less input in the integrated farming and the yield would be more sustainable because the waste of one enterprise becomes the output of another, leaving almost no waste to pollute the environment or to degrade the resource base. Integrated farming meets the potentially conflicting challenges at farm level, in a manner that balances food production, profitability, safety, animal welfare, social responsibility and environmental care. Integrated farming seeks to reinforce the positive influences of agricultural production whilst reducing its negative impacts. It is a common sense whole farm management approach that combines the ecological care of a diverse and healthy environment with the economic demands of agriculture to ensure a continuing supply of wholesome, affordable food. It is not prescriptive because it is a dynamic concept: it
must have the flexibility to be relevant on any farm, in any country, and it must always be receptive to change and technological advances.

**Intensive Integrated Farming System (IIFS)**

IIFS refers to sustainable production on the one hand and livelihood security on the other, wherein all the components of agriculture, horticulture, forestry, livestock, poultry, fishery can be integrated in a complimentary way besides soil conservation measures, vermicompost, mushroom production apiculture and liquid manure preparation, etc. in such a way so that the farm becomes self sufficient to meet its input and other requirements. It involves agricultural intensifications, diversification, value-addition and intensive use of farm resources. To be ecologically sustainable, such intensification is knowledge-intensive rather than capital-intensive and which replace, to the extent possible, market purchased chemical inputs with farm grown biological inputs. Hence, IIFS sometimes is also referred as organic integrated farming system (OIFS). IIFS can meet the needs of poor as well as rich farmers and makes the farmer self-sufficient as well as self-reliant. Hence, the integrated farming system fulfills four major aspects of agriculture viz. economic viability, easy adaptability, ecological sustainability and social acceptability. The modern agriculture emphasize too more dimensions viz., time and space concept. Time concept relates to increasing crop intensification in situation where there is no constraint for inputs. In rainfed areas where there is no possibility of increasing the intensity of cropping, the other modern concept (space concept) can be applied. In space concept, crops are arranged in tier system combining two or more crops with varying field duration as intercrops by suitably modifying the planting method. Income through arable cropping alone is insufficient for bulk of the marginal farmers. Activities such as dairy, poultry, fish culture, sericulture, bio-gas production, edible mushroom cultivation, agro-forestry and agri-horticulture, etc., assumes critical importance in supplementing their farm income. It should fit well with farm level infrastructure and ensures fuller utilization of bye-products. Intensive integrated farming system is only the answer to the problem of increasing food production for increasing income and for improving the nutrition of small scale farmers with limited resources.

**Why Integrated Farming System?**

**Shrinkage in area under cropping**: Area under cropping is decreasing day by day to urbanization, industrialization, population, construction of buildings & highways. As a result there is sharp declining in the per capital carrying capacity of the land. The population of India is expected to increase to 137 & 166 crores, respectively, in 2030 & 2050 AD, while the cultivable land will decline to 141.3 & 131.3 million.

**Small & Fragmented holding**: The average holding of a farm in India has been declining & over 80% of operational holdings are below the size of 1.0 hectare.

**Seasonal nature of income & employment & out-migration**: Cropping activities in rainfed areas areas are restricted to four months in rainy season. Employment opportunities
are scarce in other seasons. This leads to large-scale migration of male farmers to cities in search of work. Round the year employment opportunities should be there to check out-migration from rural areas.

**Deterioration of resource base**: The ultimate goal of sustainable agriculture is to conserve of human population over a longer period. This can be achieved by seeking the optimal use of internal production inputs in a way that provide acceptable levels of sustainable crop productivity & livestock production resulting in economically profitable return.

**Household requirement**: A country or state is said to achieve complete food & nutritional security if each & every person is able to consume a minimum quantum & quality of various food ingredients i.e adequate & balanced diet on a regular basis, minimum education. Other requirements include timber system approach is essential for meeting all these diverse needs from limited land holdings of small & marginal farmer.

**Advantages of Integrated Farming System**

**Productivity**: IFS improves space utilization and provides an opportunity to increase economic yield per unit area per unit time by virtue of intensification of crop and allied enterprises. The system improves soil fertility and soil physical structure from appropriate crop rotation and using cover crop and organic compost. IFS also reduces weeds, insect pests and diseases from appropriate crop rotation. IFS also ensures rejuvenation of system productivity.

**Profitability**: Use waste material of one component at the least cost. Thus reduction of cost of production and form the linkage of utilization of waste material, elimination of middleman interference in most input used. Working out net profit B/ C ratio is increased.

**Sustainability**: Organic supplementation through effective utilization of by products of linked component is done thus providing an opportunity to sustain the potentiality of production base for much longer periods. IFS avoids deforestation and thus provides sustainability to the ecosystem.

**Balanced Food**: Different components of varied nature enables to produce diversified products and different sources of nutrition. IFS ensures food & nutritional security.

**Environmental Safety**: In IFS waste materials are effectively recycled by linking appropriate components, thus minimize environment pollution and maintain agro-ecological equilibrium.

**Recycling**: Effective recycling of crop residues, livestock wastes and other unutilized resources in IFS.

**Adoption of New Technology**: Resource rich farmers fully utilize technology. Money flow round the year from different components also gives an inducement to the small/original
farmers to go for the adoption technologies.

**Saving Energy:** To identify an alternative source to reduce our dependence on fossil energy source within short time. Effective recycling technique the organic wastes available in the system can be utilized to generate biogas. Energy crisis can be postponed to the later period.

**Meeting Fodder Crisis:** Every piece of land area is effectively utilized. Plantation of perennial legume fodder trees on field borders and also fixing the atmospheric nitrogen. These practices will greatly relieve the problem of non – availability of quality fodder to the animal component linked.

**Solving Fuel and Timber Crisis:** Linking agro- forestry appropriately the production level of fuel and industrial wood can be enhanced without determining effect on crop. This will also greatly reduce deforestation, preserving our natural ecosystem.

**Employment Generation:** Combing crop with livestock enterprises would increase the labour requirement significantly and would help in reducing the problems of under employment to a great extent IFS provide enough scope to employ family labour round the year.

**Agro-industries:** When one of produce linked in IFS are increased to commercial level there is surplus value adoption leading to development of allied agro-industries. Thus IFS enhances opportunities for agriculture based industries.

**Increasing Input Efficiency:** IFS provide good scope to use inputs in different component greater efficiency and benefit cost ratio. Hence, IFS ensured less reliance to outside inputs – fertilizers, agro-chemicals, feeds, energy etc.

**Income Rounds the year:** Due to interaction of enterprises with crops, eggs, milk, mushroom, honey, cocoons silkworm. Provides flow of money to the farmer round the year. Thus, IFS improves standard of living of the farm families in spheres of food, clothing, shelter, health & education.

**Scope of Integrated Farming System**

- Farming system enterprises include crop, livestock, poultry, fish, agro-forestry etc.
- A combination of one or more enterprises with cropping, when carefully chosen, planned and executed, gives greater dividends than a single enterprise, especially for small and marginal farmers.
- Farm as a unit is to be considered and planned for effective integration of the enterprises to be combined with crop production activity.
- Integration of farm enterprises to be combined on many factors such as:
  - Soil and climatic features of the selected area.
  - Availability of resources, land, labour and capital.
  - Present level of utilization of resources.
Methodology to Organize Farming Systems under On-Farm Conditions

✓ Farm selection: Select the agro-ecological zone in which FSR is to be initiated. If necessary, further divide this agro-ecological zone to identify specific farming situation.

✓ Selection of villages and farmers: Select the village in each farming situation comprising marginal / small and medium / large farmers. Selection of village and farmers should be random so as to represent all farming community of the target area.

✓ Diagnosis of constraints in increasing farm productivity: Carry out survey through rapid rural appraisal. Prepare an inventory of farm resources and support services. Identify the production constraints.

✓ Research, design and technology generation and adoption

✓ Technology transfer and diffusion of improved farming systems within recommended domain.

✓ Impact of technology of improved farming system – productivity, economic returns, energy input – output, employment, equity (gender issue) and environment.

Principles of Integration

In agriculture, crop production is the main activity. The income obtained from crops may hardly be sufficient to sustain the farm family throughout the year. Assured regular cash flow is possible when the crop is combined with other enterprises. Judicious combination of enterprises, keeping in view of the environmental conditions of a locality will pay greater dividends. At the same time, it will also promote effective recycling of residues/wastes. Hence, the following principles of integration need to be considered for a successful farming system.

✓ The system should produce sufficient high quality food, fiber, fodder and industrial raw material

✓ The system should meet the demands of the society

✓ The system should maintain a viable farming business

✓ The system should care for the environment

✓ The system should sustain the natural resources

Ideal Situations for Introduction of Farming System
The farmer wants to improve the soil quality and fertility
The farm household is struggling to buy food or below the poverty line
The farmer is seeking to maximize profits on existing holding
The farmer is looking to reduce chemical control methods
The farmers wants to gain profits from allied activities
The farm is being eroded by wind or water
Chemical inputs are expensive or unavailable
Soil fertility has been decreased as a result of inorganic fertilizer use
The farm has been suffering from water scarcity
The land is fragmented
The community wants to reduce pollution
The community wants to maintain biodiversity

Major Components of IFS (Prakash et al., 2015; Roy et al., 2014 and 2015)

<table>
<thead>
<tr>
<th>A. Crop</th>
<th>B. Livestock &amp; Poultry</th>
<th>C. Fishery</th>
<th>D. Secondary Agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>Cattle</td>
<td>Composite fish culture</td>
<td>Bee keeping</td>
</tr>
<tr>
<td>Pulses</td>
<td>Buffalo</td>
<td>Fingerling production</td>
<td>Mushroom cultivation</td>
</tr>
<tr>
<td>Oilseeds</td>
<td>Pig</td>
<td>Paddy cum fish culture</td>
<td>Food processing</td>
</tr>
<tr>
<td>Fruits</td>
<td>Goat</td>
<td></td>
<td>Vermicomposting</td>
</tr>
<tr>
<td>Vegetables</td>
<td>Sheep</td>
<td></td>
<td>Biogas production</td>
</tr>
<tr>
<td>Spices</td>
<td>Chicken</td>
<td></td>
<td>Azolla cultivation</td>
</tr>
<tr>
<td>Plantation crops</td>
<td>Duck</td>
<td></td>
<td>Sericulture</td>
</tr>
<tr>
<td>Flowers</td>
<td></td>
<td></td>
<td>Moriculture</td>
</tr>
<tr>
<td>Fodder/forage crops</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agro-forestry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugarcane</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Fibre crops</td>
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</tbody>
</table>

An IFS can be developed by integrating the above four components (A+B, A+C, B+C, A+D, B+D, C+D, A+B+C, A+B+D, A+C+D, B+C+D, A+B+C+D). Selection of crops, livestock, fishery and secondary agricultural activities depend on farmers’ preference, suitable agro-climate, available technology and marketing facility.
A Conceptual Framework of IFS Integrating Various Components (Roy et al. 2014)

The conservation of natural resources employing the modern concepts of farming systems is essential for sustainable agricultural development and ensuring greater livelihood securities to the poor people of ecologically handicapped areas. Hence, natural resource management (NRM) is an integral part of IFS. NRM refers to the management of natural resources such as land, water, soil, plants and animals, with a particular focus on how management affects the quality of life for both present and future generations. Natural resource management is congruent with the concept of sustainable development, a scientific principle that forms a basis for sustainable global land management and environmental governance to conserve and preserve natural resources. Natural resource management specifically focuses on a scientific and technical understanding of resources and ecology and the life-supporting capacity of those resources. NRM issues are inherently complex as they involve the ecological cycles, hydrological cycles, climate, animals, plants and geography etc. All these are dynamic and inter-related. A change in one of them may have far reaching and/or long term impacts which may even be irreversible.

A natural resource is often characterized by amounts of biodiversity existent in various ecosystems. NRM refers to the management of natural resources such as land, water, soil, plants and animals, with a particular focus on how management affects the quality of life for both present and future generations. Natural resource management is congruent with the concept of sustainable development, a scientific principle that forms a basis for sustainable global land management and environmental governance to conserve and preserve natural resources. Natural resource management specifically focuses on a scientific and technical understanding of resources and ecology and the life-supporting capacity of those resources. The term Environmental management is also similar to natural resource management. NRM issues are inherently complex as they
involve the ecological cycles, hydrological cycles, climate, animals, plants and geography etc. All these are dynamic and inter-related. A change in one of them may have far reaching and/or long term impacts which may even be irreversible. In addition to the natural systems, NRM also has to manage various stakeholders and their interests, policies, politics, geographical boundaries, economic implications and the list goes on. It is very difficult to satisfy all aspects at the same time. This results in conflicting situations.

Integrated natural resource management (INRM) is a process of managing natural resources in a systematic way, which includes multiple aspects of natural resource use (biophysical, socio-political, and economic) meet production goals of producers and other direct users (e.g., food security, profitability, risk aversion) as well as goals of the wider community (e.g., poverty alleviation, welfare of future generations, environmental conservation). It is focuses on sustainability and at the same time it tried to incorporate all possible stake holders from the planning level itself, reducing the possible conflicts in future. The conceptual basis of INRM has evolved in recent years through the convergence of research in diverse areas such as sustainable land use, participatory planning, integrated watershed management, and adaptive management. INRM is being used extensively and been successful in community based natural management.

The Community Based Natural Resource Management (CBNRM) approach combines conservation objectives with the generation of economic benefits for rural communities. The three key assumptions being that; locals are better placed to conserve natural resources, people will conserve a resource only if benefits exceed the costs of conservation and people will conserve a resource that is linked directly to their quality of life. When a local people’s quality of life is enhanced, their efforts and commitment to ensure the future well-being of the resource is also enhanced. CBNRM is based particularly on advocacy by nongovernmental organizations working with local groups and communities, on the one hand, and national and transnational organizations, on the other, to build and extend new versions of environmental and social advocacy that link social justice and environmental management agendas with both direct and indirect benefits observed including a share of revenues, employment, diversification of livelihoods and increased pride and identity. CBNRM has raised new challenges, as concepts of community, territory, conservation, and indigenous are worked into politically varied plans and programs in disparate sites. Major emphasis should be given on erosion management (preventive and control measures), water conservation (in-situ, run-off and water table management), soil fertility management (management of nutrients, acidity, soil biological activity and nutrient recycling) and vegetation management (crops, trees and pastures management). The following measures can be undertaken for efficient management of soil and water resources in an integrated farming system.
Training Manual on "Integrated Farming System for Sustainable Hill Agriculture: An Option for Climate Smart Agriculture and Natural Resource Management"

<table>
<thead>
<tr>
<th>Soil Conservation</th>
<th>Water Conservation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench terracing</td>
<td>Zingg terracing</td>
</tr>
<tr>
<td>Half moon terracing</td>
<td>Micro-watershed</td>
</tr>
<tr>
<td>Bunding (contour, graded)</td>
<td>Community pond</td>
</tr>
<tr>
<td>Gully development / Gully plugging</td>
<td>Water harvesting (rain, runoff, roof etc.)</td>
</tr>
<tr>
<td>Contour trench</td>
<td>Dew harvesting</td>
</tr>
<tr>
<td>Hedge row planting</td>
<td>Gully plugging</td>
</tr>
<tr>
<td>Cover cropping</td>
<td>Check dam</td>
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<tr>
<td>Intercropping</td>
<td>Catch pit</td>
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<tr>
<td>Strip cropping</td>
<td>Scooping</td>
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<tr>
<td>Alley cropping</td>
<td>Contour trench</td>
</tr>
<tr>
<td>Mulching (Horizontal/stubble)</td>
<td>Percolation tank</td>
</tr>
<tr>
<td>Grass waterway/Vegetative barriers</td>
<td>Mulching (Vertical)</td>
</tr>
<tr>
<td>Planting across the slope</td>
<td>Micro irrigation</td>
</tr>
<tr>
<td>Conservation tillage</td>
<td>Conservation tillage</td>
</tr>
<tr>
<td>Manuring / Integrated nutrient management</td>
<td>Furrow management (ridge &amp; furrow, tied ridging, board bed furrow, dead furrow etc.)</td>
</tr>
<tr>
<td>Soil amendments</td>
<td>Compartmental building</td>
</tr>
<tr>
<td>Biological enrichment of soil</td>
<td>Multiple use of water</td>
</tr>
<tr>
<td>Windbreaks, Shelterbelts and soil binding crops</td>
<td>Perennial horticulture/Agro-forestry</td>
</tr>
<tr>
<td>Application of chemicals for aggregate stability (e.g. Poly vinyl alcohol, bitumen)</td>
<td>Organic agriculture</td>
</tr>
<tr>
<td>Reclamation of cultivable land</td>
<td>Revitalization of Traditional Water harvesting structures</td>
</tr>
</tbody>
</table>

Integrated farming system has the advantages of increasing economic yield per unit area per unit time, profitability, sustainability and provides balanced nutritious food for the farmers, pollution free environment and provide opportunity for effective recycling of one product as input to other component, money round the year and solve the energy, fodder, fuel and timber crisis, avoids degradation of forests and enhance the employment generation, increase input use efficiency and finally improve the livelihood of the farming community. Integrated farming systems have emerged as a well-accepted, single window and sound strategy for harmonizing simultaneously joint management of land, water, vegetation, livestock and human resources. A number of such illustrations can be given emphasizing the greater advantage of integrated farming system in generating technologies aimed at combating land degradation. It is this approach that can lead to a quantum jump in the productivity on a sustainable basis and ensure better livelihood securities to the people in fragile ecosystems. Hence, the future agricultural system should be reoriented from the single commodity system to integrated farming system for sustaining food and nutritional security.
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Climate smart technologies for resource poor farmers’ of North East Hill India

S. Hazarika and Anjan Kumar Sarma

ICAR RC for NEH Region, Umiam-793 103, Meghalaya

Agricultural production system in North East Hill (NEH) region is predominantly rainfed and the region facing multifarious challenges like degradation of natural resources especially land degradation with jhum cultivation, fragmentation of land holdings, occurrence of dry spells in undulating hill topography, securing food for increasing population and low crop productivity. Gradual degradation of natural resources is the prime concern and calls for location specific measures to conserve, utilise and manage such resources for optimising production on sustained basis without adversely affecting its quality.

There have been some conspicuous changes in temperature as well as rainfall pattern in northeast India over the past century. The annual maximum and mean temperature in northeast India during 1901-2003 has increased significantly by a rate of 1.02 °C and 0.60 °C/100 years, respectively (Deka et al. 2009). Atmospheric temperature in the region is further projected to rise by approximately 3°C to 5°C during the latter third of this century (Cline, 2007). There is reduction in the annual as well as the monsoon rainfall over the years in the north-east. In the recent times, the alarming deficits in annual as well as monsoon rainfall resulted in severe droughts across the region. The shift in the climatic scenario and lack of mitigation strategies with the farmers makes the challenges in agriculture further complex. Since 80% of the crop area is under rainfed, future climate change and variability will potentially impact agricultural production pattern in the region (Ministry of Environment and Forests Report 2004, GOI). In the context of climate change and variability, farmers need to adapt quickly to enhance their resilience to increasing threats of climatic variability. Over the few years, number of climate resilient technologies has been developed in the region by many researchers for sustaining agricultural production and improvement of livelihood. Adoption of such climate resilient technologies by farmers’ is to be an option for sustainable agriculture under changing climatic condition. Some climate resilient technologies in different agricultural sectors for improvement of livelihood of resource poor farmers’ of NEH region are described hereunder (Source: NICRA Research Highlights, 2016)

1. Land use model for soil and water conservation and carbon sequestration:
The technology can be adopted for hill slopes (30-40%) to enhance water and nutrient use efficiency through in situ moisture conservation practices. The technology involves maintenance of natural forest at hill top with catch pit (1.5 x 0.5 x 0.3m), cultivation of fodder crops (Broom, Congo, Hybrid Napier and Guinea grass) followed by cover crops (groundnut, soybean, rice bean & cowpea) in lower terraces, intercropping (maize with groundnut, soybean, rice bean and cowpea) and rice- lentil system under conservation
tillage. Hedge row species in contour or alternate risers and toe trenches to reduce runoff and increase infiltration. Micro rain water harvesting structure (*Jalkund*) at the bottom of the slope for storing rain water which can be used for life saving irrigation during dry season. The model is developed exclusively for soil and water conservation as well as building up of soil organic carbon for improving/sustaining productivity in hill slopes (30-40%) of NE India.

2. **Zero tillage cultivation of pea/rapeseed/lentil in rice fallow:**
The technology can be adopted for crop diversification and resource conservation in hilly ecosystem. The benefits of the technology are:

- helps timely sowing of pea/rapeseed/lentil after harvest of the rice
- conservation and efficient utilization of residual moisture of rice crop
- reduces cost of cultivation due to savings in fuel, labour and energy
- less erosion due to less disturbance of soil surface
- improves soil health due to less disturbance and enhanced microbial activity
- increases cropping intensity and higher net income

With the zero tillage technology, farmers can not only enhance crop yield but also improves water economy during dry period by encouraging downward movement of water across the root boundary. The technology provides ample opportunity for sustaining crop production in hilly ecosystem of NE region.

3. **Micro rain water harvesting structure (*Jalkund*):**
The technology is simple and low cost and developed for storing rain water in the upper terrace condition. Large scale adoption of this technology and its judicious use provides new livelihood options for the resource poor farmers of this region. *Jalkund* offers a unique opportunity to the farmers’ in increasing agricultural productivity and diversifying their homestead farming by growing highly remunerative crops and rearing cattle, pig, poultry etc.

4. **Soil moisture conservation by land configuration:**
Land configuration means mechanical manipulation of existing surface terrain of the land (making bunds, ridges and furrows or raised and sunken beds). The technology can be used for *in situ* harvesting of rain water because, it allows rain water to infiltrate into the deeper soil layers and thereby, improves soil moisture storage. Land configuration is done to avoid water stagnation in crop fields when cultivating vegetables in rice fallows.

5. **Climate resilient cropping system:**
Maize (Green cob)-Pahelo dal (Urad bean) – Buckwheat cropping system is a climate resilient cropping system under rainfed ecosystems of mid hills of Sikkim. Adoption of such cropping system gives maximum system productivity, profitability (B:C ratio 2.55) and employment generation.

6. **Climate resilient deep litter housing model for pig:**
Climate resilient low-cost deep litter housing model for pigs was designed and developed using locally available resources (bamboo, tree leaves, saw dust etc) which is suitable for
high rainfall at mid/high altitude region. The low temperature in conventional concrete pen model causes energy loss to pig resulting stress during winter months. Application of saw dust on the floor of deep litter housing model keep it warm during winter months and provide comfortable environment to pigs. In rainy season, the conventional pig pen remains wet and has higher temperature humidity index (THI) as compared to deep litter housing that results in high growth rate and disease resistance. The benefits of adoption of this technology are:

- provides better micro-environment for pig in both summer and winter
- better physiological adaptation of breeds
- less incidence of disease
- protecting animal welfare and snouting as well as other behaviours
- faster growth rate of piglets and higher performance and productivity
- ten times higher water productivity by rain water harvesting
- higher quantity of manure production (1.5 times) as compared to conventional housing model

Conclusions:

The development of agricultural technologies that are resilient to stress is the need of the hour to deal with the adverse impact of climate change on agriculture. Appropriate transfer of such climate smart technologies will enable farmers to deal with the adverse impact for sustaining their livelihood.

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Climate resilient sustainable intensive integrated farming system for resource conservation and sustainable livelihood

Anup Das
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Introduction

India presently supports world’s 18% human population and 15% livestock population with merely 2.4% land mass and 4.2% fresh water, and the pressure on these finite resources is swelling due to an ever-increasing population. Rise in human population is linked to rising in demand for water, with agriculture being the major consumer. The soil, water, minerals and plant resources are currently under tremendous pressure owing to competing and conflicting demands of increasing population. Consequently, over exploitation and mismanagement of resources are exerting detrimental impact on environment. It is estimated that by 2050, the food grain requirement of India will be 377 Mt to feed about 1.6 billion populations. Sustainable and increased productivity depends solely on natural resources of land, water and vegetation, which need to be judiciously managed to meet the growing needs of food requirements and maintain environmental security for future generations. Shrinking and degrading natural resources, and changing climate, however, limit the ability to attain the consumptive lifestyle that is commensurate with expected increase in income levels. Managing soil and water resources, including degraded ones, to meet growing human and animal needs in terms of food, fibre, fodder, timber and fuel are therefore considered of paramount importance in the present context as well as of the future. Thus, location specific resource conservation technologies (RCTs) like conservation agriculture comprising no-till/minimum tillage, residue retention, crop diversification/rotation, raised and sunken beds, system of rice intensification, integrated crop management, in situ residue retention, integrated nutrient and water management, land leveling, efficient water management like micro-irrigation, etc. are to be promoted for sustainable agriculture, climate resilience and food security.

There is no general agreement on the extent of anticipated warming, but expectations are of 0.5°C – 2°C by the year 2030 (UN 2012). Because of climate change, Indian agriculture is doubly vulnerable. First as around 60 percent of India’s total agricultural areas are rain-fed, it is highly vulnerable to climate change impacts on monsoon. Secondly, more than 80 percent of farmers in India are small and marginal with less than 1 ha of land, thus having less capacity to cope with climate change impacts on agriculture. India’s 200 backward districts as ranked by the Planning Commission are distinguished for the large-scale practice of rain-fed agriculture. With the changing food habits and market conditions, farmers prefer wheat or rice in most parts of the country. In most agro-climatic regions, farmers have stopped cultivation of millets which are suitable to a particular agro-climatic region. Climate change is projected to have serious
implications for these major crops especially wheat. The studies have already projected greater losses in rabi season (e.g. in wheat yield) as compared to kharif crops. The key characteristics of Indian agriculture that could influence/increase its vulnerability to climate change are (i) high level of subsistence agriculture with small land holdings (ii) majority of agriculture is rain-fed (iii) frequent occurrence of extreme weather events such as droughts and cyclones and (iv) the wide variation in agricultural productivity across the country (Ranuzzi and Srivastava 2012). According to the IPCC, the next few decades of climate change are likely to bring benefits to higher latitudes through longer growing seasons, but in lower latitudes, even small amounts of warming will tend to decrease yields (IPCC 2012). Dealing with climate change would require strengthening the resilience of farmers and rural communities and help them adapt to the impact of climate change. The key to developing appropriate and targeted adaptation efforts is to understand impact of climate change across different agro-climatic regions. The impact of climate change on behaviour of pests and diseases still remains largely unclear, while their economic implications are being increasingly felt (Ranuzzi and Srivastava, 2012).

Adoption of conservation agriculture (CA) principles in crop production and integrated farming systems for efficient recycling of on- and off-farm biomass are the two simple and environmentally sustainable technologies for achieving twin objectives in food and environmental security. Agroforestry has significant role in reversing trend of land degradation and improve livelihood, ecosystems services in terms of C-sequestration and soil water conservation. Thus, for ensuring food and nutritional security in one hand and conserving natural resources and ensuring environmental security, on the other hand; there is urgent need to employ and adopt conservation effective best practices in various aspects of agriculture and allied sectors. National Innovation on Climate Resilient Agriculture (NICRA) is being implemented by ICAR to address the impact of climate variability and climate change in agriculture and to develop appropriate technologies for bringing resilience to the agricultural production systems. During last four years, a good number of location-specific technologies including resource management modules, low carbon technologies, crop varieties, livestock breeds have been identified and demonstrated under technology demonstration component in farmer’s field for a climate smart farming.

Agriculture is the most vulnerable sector to climate change as it is inherently sensitive to climate variability and climate change will leave its impacts on Indian agriculture in various direct and indirect ways. This obviously means an impact on the lives and livelihoods of millions of Indians. It is reported that about two-thirds of the sown area in the country is drought-prone and around 40 million hectares is flood-prone. The poorest people are likely to be hardest hit by the impacts of climate variability and change because they rely heavily on climate-sensitive sectors such as rainfed agriculture and fisheries. They also tend to be located geographically in more exposed or marginal areas, such as floodplains, hills & mountainous regions or nutrient-poor soils. The poor are also
less capable to respond due to limited human, institutional and financial capacity and have very limited ability to cope with climate impacts and to adapt to a changing hazard burden. Climate change will have far-reaching consequences for agriculture that will disproportionately affect poor and marginalized groups who depend on agriculture for their livelihoods and have a lower capacity to adapt (World Bank, 2007). Climate-related crop failures, fishery collapses and livestock deaths already cause economic losses and undermine food security, and these are likely to become more severe as global warming continues. A recent study estimates the annual costs of adapting to climate change in the agricultural sector to be over US$ 7 billion (Nelson et al., 2009).

The impact of climate change in northeast India is equally alarming in terms of eco-fragility, marginality and inaccessibility making the future agricultural scenarios more uncertain and risk-prone. The irregular pattern of rainfall with rainfall starting quite early in the region, extreme rainfall events, less rain in June-Aug, and more in Sept/Oct, and flash floods becoming more frequent and dry periods becoming longer in various parts of the region indicates impacts of visible shift/change of climate in the eastern Himalayas. Summer monsoon rainfall is found to be decreasing in this region significantly during the last century at an approximate rate of 11 mm per decade. The annual mean maximum temperatures in the region are rising at the rate of +0.11°C per decade. The annual mean temperature is also increasing at a rate of 0.04°C per decade in the region (Das 2009). At mid-altitude of Umiam, Meghalaya the maximum temperature is increasing linearly over the years whereas, the minimum temperature showed a gradually decreasing trend. Thus, there is a widening gap between maximum and minimum temperature. A similar anomaly was also observed in Jharnapani, Nagaland.

Several districts of Assam were badly affected due to drought-like situations consecutively for two years in 2005 and 2006 which had a signature of climate change on them as indicated in the IPCC report of 2007 (IPCC, 2007a). The year 2005 saw prolonged dry periods in Mizoram with many springs and streams drying up accompanied by large-scale landslides (ICIMOD, 2008). A similar drought and extreme events in NE India along with other parts of the country was recorded in the year 2009.

Climate change will make water availability more uncertain, both in time and space. While overall trends are difficult to decipher, there are clear indications that the frequency and magnitude of high-intensity rainfall events are increasing (Goswami et al., 2006) with negative implications on infiltration and groundwater recharge and also for long-term soil moisture and water accessibility for plants. There are also indications that the dry season is becoming drier and seasonal droughts and water stress becoming more severe. The timing and length of monsoon season are also changing.

**State wise major climate risks in NE region**
- Assam - Floods, marshy land, droughts, terminal heat stress, cyclones
- Arunachal Pradesh- Drought, Landslides, floods, low temperature
- Meghalaya- Drought, Soil and water erosion, Frost/low temperature
- Mizoram- Drought, landslides
- Manipur- Drought, floods, landslides
- Nagaland- Drought, Soil erosion
- Tripura- Droughts, terminal heat stress, Floods, Cyclones
- Sikkim- Low temperature, landslides

**Status of Natural resources in NER**

The agriculture in the North Eastern region of India is characterized by different terrain, wide variations in slopes and altitude, land tenure systems and cultivation practices. The agricultural production system in the region is mostly rainfed, mono-cropped and at subsistence level. Use of local varieties, negligible use of agro-chemicals, low moisture retention capacity of upland soil and lack of irrigation facilities along with traditional management practices have resulted in low productivity of crops and low cropping intensity in the region. Problems of high rainfall (12.1 % of country’s total precipitation), soil acidity, aluminium toxicity in upland and iron toxicity in valley land have added to the problem of low agricultural productivity in the region. The soils of the region are usually rich in organic matter and acidic to strongly acidic (pH 4.5-5.0) in reaction. Most of the hill soils are shallow in depth except in valleys and plateaus. Soil erosion is a major problem in the region due to steep slopes and faulty land use practices Slash and burn agriculture is still predominantly practiced in almost all the states except Sikkim, on steep slopes with reduced low cycle of 2-3 years as against 10-15 years in the past. This system has led to accelerated erosion, silting of reservoirs and low productivity of land and ecological imbalance well.

The region is bestowed with rich resources of soil and agro-climate, making it one of the fertile regions of the country. The vast area of hills interspersed with fertile valley represents agro-climates of unique diversity, ranging from extreme temperate to typical tropical. Coupled with this are the abundance of natural water resources, well-distributed rainfall and good soil, enabling the growth of wide variety of crops. The region offers great potential for organic food production due to varied agro climatic zones that offer production of tropical to temperate agricultural crops. Rich natural resource base, thin population density and village leadership pattern make it easy to go organic in the region.

**Land Use Pattern**

In NE Hill region (excluding the plains of Assam) only 6.4% of the total geographical area is utilized for cultivation of agricultural crops, minimum being in Arunachal Pradesh (2.06%) and maximum in Tripura (25.73%). However, there is still scope to increase the area under cultivation of agricultural crops by 47.6%. About 1910 thousand hectares is the potential land available for cultivation of agricultural crops in the region. Out of this, 0.8 5, 20.1% and 79.1% of the area is under category I, II and III of land capability classification, respectively.
The net and gross cultivated area in NE region is about 4 m ha and 5.7 m ha, respectively. The state of Assam is having maximum cultivated area followed by Nagaland and Meghalaya. Cropping intensity is highest in the state of Tripura (184%) and lowest in Mizoram (120%). The share of total cultivated area under food grain production as against total cropped area is highest in Manipur (78.7%) followed by Nagaland and Arunachal Pradesh. Except Sikkim and Tripura, all other NE states are having higher share of area under food grain production compared to national average (65%). This indicates that there is scope for diversification of food crop-based cropping systems.

Rice is the main staple food crop of the North East. All most all the social activities are some or other way related to rice-calendar. Cropping systems in the NER is also predominantly rice based with the little exception in the state of Sikkim where maize is the main food crop. Rice cultivation in the region is under low-input low-risk and low yield condition. In the low land mostly mono-cropping of rice is practiced with the little exception in Tripura, Assam, parts of Garo hills where rice-rice system is practiced. After rice harvest in valley lands, soil moisture remains very high mainly due to seepage from surrounding hillocks. Therefore, with proper land configuration, the residual soil moisture could be effectively utilized for vegetable cultivation. This would not only increase the farmer’s income but would also double the cropping intensity in valley land. Making raised bed or bun, a local practice, where all the crops and weed residues are kept on the surface of the soil, above which raised beds are prepared. This type of cultivation not only improves the soil physicochemical properties but also improves productivity. In the upland rice-mustard, rice-vegetable system is practiced to some extent. The main reason of low productivity of rice in the region is non-utilization of improved technology including improved and recommended varieties. The farmers in the NE (excluding parts of Assam, Tripura and Manipur) are still practicing age-old wetland direct seeding (>90 % of total area) and remaining area transplanted without any systematic manner (<10).

**Agro-climatic conditions and status of food grain production in North East India**

The NE Region has 8 distinct agro-climatic zones starting from subtropical to temperate to Alpine zone. Each state has been divided into agro-eco-zones for agricultural planning and development. In Arunachal Pradesh, there are 5 agro-eco-zones and rice is the main crop of the state. Tropical and temperate fruits are also grown. In Assam, having 3 agro-eco-zones, double cropping of rice is practiced in plains. Fish farming in large marshy bodies is also common. Tea husbandry is common in the state of Assam. Manipur having 3 agro-eco-zones, rice, fruits, vegetables, spices are major crops. Meghalaya has got 5 different agro-eco-zones and rice, maize, ginger, turmeric, citrus etc. are important crops. Rice is grown on the terraces of Mizoram (3 agro-eco-region) with horticultural crops in slopping areas. Nagaland has got 4 climatic zones where rice is cultivated in valleys and horticultural/plantation crops in the hills. In Sikkim (4 agro-eco-zone zones), where agriculture is well established on bench terraces of 30-50% slopes on which maize, horticultural/plantation crops are grown. Cardamom and temperate orchid are plenty in
Sikkim. In Tripura, there are 3 agro-eco-regions where double cropping of rice is prevalent in plains. Pigeon pea, black gram, lentil, sesame, mustard, pineapple, areca nut, tea and vegetables are grown.

The region as a whole is deficit of about 0.21 million tons (2.51% deficiency) of food grains for an estimated population of 47.9 million (m) in 2014 (Table 1). The projected food grain demand for NER is 10 mt. and 12.5 mt. for the year 2020 and 2030, respectively. In order to make the region self-sufficient in food grain production, productivity of all the food crops has to be increased with effective utilization of natural resources and wide variety of climatic conditions. Drought, floods, cold, pest and disease problems owing favourable climatic condition are the major concern for food security. The drought of 2009 is believed to have reduced rice production by about 20-30% in the North Eastern Region.

Fruits and vegetable sectors experienced tremendous growth in the region during last decade. The decadal growth in fruit and vegetable sectors in the NE region was 44.06 and 49.71 % as against 94.7 and 43.8% at the National level, respectively. Almost all the states are now a surplus in fruits and vegetables except some deficiencies in Arunachal Pradesh and Nagaland. There is large deficiency in fish (-48.6%), milk (-66.6%), egg (-86%) and meat (-56.8%) in the region. Effective utilization of natural resources coupled with the use of high yielding varieties and an optimum package of practices would certainly reduce the gap to a great extent.

Table 1: Production and requirement of food grains, rice, pulses, fruits, vegetables, fish, milk, egg and meat in NE Region in 2014.

<table>
<thead>
<tr>
<th></th>
<th>Production</th>
<th>Requirement</th>
<th>Deficit surplus</th>
<th>Deficit surplus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Grains</td>
<td>8232.82</td>
<td>8444.66</td>
<td>-211.84</td>
<td>-2.51</td>
</tr>
<tr>
<td>Rice</td>
<td>6805.28</td>
<td>7522.34</td>
<td>-717.06</td>
<td>-9.53</td>
</tr>
<tr>
<td>Pulses</td>
<td>159.84</td>
<td>874.41</td>
<td>-714.57</td>
<td>-81.72</td>
</tr>
<tr>
<td>Fruits</td>
<td>4457.57</td>
<td>2098.59</td>
<td>2358.98</td>
<td>52.92</td>
</tr>
<tr>
<td>Vegetables</td>
<td>5176.58</td>
<td>5222.51</td>
<td>-45.93</td>
<td>-0.88</td>
</tr>
<tr>
<td>Fish</td>
<td>320.09</td>
<td>622.87</td>
<td>-302.78</td>
<td>-48.61</td>
</tr>
<tr>
<td>Milk</td>
<td>1169.12</td>
<td>3497.65</td>
<td>-2328.53</td>
<td>-66.57</td>
</tr>
<tr>
<td>Eggs (lakh nos.)</td>
<td>10008.65</td>
<td>71869.45</td>
<td>-61860.80</td>
<td>-86.07</td>
</tr>
<tr>
<td>Meat</td>
<td>227.72</td>
<td>527.04</td>
<td>-299.32</td>
<td>-56.79</td>
</tr>
</tbody>
</table>

Note: Fish and meet requirement has been worked out@ 13kg & 11 kg/person/year

Existing Farming Systems

The two distinct agricultural practices prevalent in the region are settled farming practiced in the plains, valleys, foothills and terraced slopes, and shifting cultivation in hills. Shifting cultivation, locally known as jhumming is a widely practiced farming system in the hills of northeast India. This most primitive form of agriculture is still common amongst the tribal people in various pockets. This system involves cultivation of crops on steep slopes. The land is cleared by cutting of forests, bushes etc. up to the stump level in
Training Manual on "Integrated Farming System for Sustainable Hill Agriculture: An Option for Climate Smart Agriculture and Natural Resource Management

December – January, leaving the cut materials for drying and final burning to make the land ready for dibbling of seeds of different crops before the onset of rains. Upland rice is the main crop grown in mixtures with maize, finger millet, foxtail millet, beans, tapioca, yam, banana, sweet potato, ginger, chillies, sesame and vegetables. All these crops are grown as rainfed without tilling the land and harvesting starts from August onwards. Maize and cucurbits are first available for consumption. Rice harvesting starts with the maturity of panicles, which are picked up in time leaving behind the stubbles in the jhum field to decompose. During the second year, usually, a single crop of rice is grown. After two to three years of cultivation, the land is left fallow for regeneration of the forest vegetation and soil fertility to be used again after some years. Various other forms of indigenous farming practiced in different states of the northeast region are described below.

Shifting cultivation is still prevalent in large scale in North East. Recent data on area and families involved in this practice is not available. In 1983, the Task Force on shifting Cultivation estimated the total area under this system was 1.47 m ha and 0.44 m tribal families were engaged. The area under shifting cultivation is minimum in Assam. The Task Force reported jhum cycle of 2-10 years in Assam to 5-9 years in Tripura. Of late (1999) Forest Survey of India estimated the cumulative area of 1.73 m ha affected by shifting cultivation and maximum area affected was reported in Nagaland, Mizoram and Manipur. It is striking to note that Sikkim doesn’t have an area under shifting cultivations and terraced cultivation with permanent agriculture is prevalent in Sikkim. The productivity of Jhum land is very low, especially where the jhum cycle is shorter (2-3 years). For higher productivity of jhum, improved practices like proper soil and water conservation measures, good agro-techniques viz., improved variety, planting across the slope etc. need to be followed.

The important farming systems of the region with the base of resource conservation and their effective utilization are presented in Table 2. All these systems use local low yielding long duration varieties and breeds. However, with the increase in population, the pressure on land is increasing and farmers are moving towards intensive cultivation, which is causing further degradation of natural resources. For long-term sustainability, viable alternative farming system strategies like the agri-horti-pastoral system, terraced cultivation etc. has to be followed. ICAR Research Complex for NEH Region, Umiam, Meghalaya developed a model involving 1/3rd of the top hill for forestry, middle 1/3rd for horticultural crops and remaining 1/3rd-foot hills for agricultural crops.

Table 2. Major indigenous farming systems of the North East India and their specific characteristics.

<table>
<thead>
<tr>
<th>Farming systems</th>
<th>State</th>
<th>Resource conservation methods followed</th>
<th>Rice productivity (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panikheti system of rice cultivation</td>
<td>Nagaland, Sikkim, Manipur</td>
<td>Terracing, diverting water from hills to terraces, green leaf manuring, in-situ residue management</td>
<td>2.5-3 t/ha</td>
</tr>
<tr>
<td>Apatani method of rice cultivation</td>
<td>Apatani plateau of Arunachal Pradesh</td>
<td>Rice + fish integration, soil and water conservation, in-situ residue management,</td>
<td>4-4.5 t/ha</td>
</tr>
</tbody>
</table>
Zabo farming

Phek District of Nagaland

Forest in the upper hills, animal shed in mid hill slopes, water harvesting tank down the cattle shed and finally the rice/crop field. Green leaf manuring with alder litters. Paddy husk is used to plug the bunds to reduce seepage loss. Tank silts are used in crop fields.

3-3.5 t/ha

Alder based farming system

Nagaland

Alder (Non leguminous nitrogen fixing plant) tree is lopped to maintain a height of about 2 m. The leaves and biomass are managed for soil fertility.

2-2.5 t/ha

Bun method (Raised beds)

Meghalaya

Dry vegetation/biomass as source of manure, legumes as companion crops

18-20 t/ha potato

Bambo drip irrigation

Jaintia hills of Meghalaya

Drip irrigation using bamboo/banana pseudostem.

Good arecanut productivity

Cattle shed rotation in upland

Sikkim

Temporary cattle shed is made in field to harvest urine, cow dung and litters

Organic production of ginger and cole crops

Pond based farming systems

Plains of Tripura, Assam, Manipur

Farm pond near homestead or within paddy field, Fish + livestocks + arecanut + kitchen garden + vegetables + rice, use of Farmyard manure, composts, lifesaving irrigation with harvested water in ponds

3.5-4.0 t/ha

Note: The pest and disease in these systems are managed by following indigenous means like crab trap, plant extracts, wood ash etc. In pond based farming systems in plains low level of fertilizer (20 kg/ha) and pesticides are used.

Improved Integrated Farming Systems for North East India

Farming system approach requires involvement of agriculture, horticulture, soil conservation, forestry, fisheries, animal husbandry, apiculture, agriculture, sericulture, etc. Soil and water conservation are affected through contour bunds in low rainfall areas and graded bunds or bench terraces in high rainfall areas. Half-moon terraces are practiced in hill slopes for planting horticulture plants. Water harvesting structures in the form of small farm ponds or community large ponds are constructed and integrated with the fishery, duckery, piggery etc. Gulley plugging is to be resorted to wherever needed. Out of several alternative land use systems, the agri-horti-silvi-pastoral system was found to be most economical with effective soil and water conservation measures in the northeast. Topo-sequential cropping involving agroforestry in the top portion, horti-pastoral crops in the middle and agricultural crops like rice, maize/popcorn, soybean, groundnut etc. are to be grown in the lower portion of the hills for effective management of land and water resources. It is also possible to integrate different components of the ecosystem (land, water, plant species etc.) to obtain sustained production from waste, rainfed and degraded lands to check natural hazards like floods, drought and soil erosion. Special attention is required in selecting a proper site according to slope, plant species and management of the agri-horti-silvi-pastoral system in respect of land capability, water harvesting and cultural practices.

Under National Agricultural Innovation Project (NAIP) following location specific farming systems were found promising for sustainable rural livelihood in NER (Table 3).
Table 3: Site specific recommended livelihood models for the disadvantaged districts of NE India

<table>
<thead>
<tr>
<th>Model</th>
<th>Location</th>
<th>Beneficiaries (nos.)</th>
<th>Total area covered (ha)</th>
<th>Investment (Rs./ha)</th>
<th>Gross return (Rs./ha)</th>
<th>Net return Rs./ha/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agro-forestry based farming system</td>
<td>Mon, Dhalai, Upper Subansiri</td>
<td>145</td>
<td>142.5</td>
<td>23,731</td>
<td>47,134</td>
<td>33,300</td>
</tr>
<tr>
<td>SRI/ICM intervention in rice</td>
<td>Dhalai and South Garo Hills</td>
<td>1263</td>
<td>1680.0</td>
<td>24,250</td>
<td>54,350</td>
<td>30,100</td>
</tr>
<tr>
<td>Zero tillage toria cultivation in rice</td>
<td>Tamenglong</td>
<td>915</td>
<td>576.4</td>
<td>25,000</td>
<td>54,000</td>
<td>15,000</td>
</tr>
<tr>
<td>Fish based integrated farming system</td>
<td>Dhalai, South Garo Hills and Tamenglong</td>
<td>1214</td>
<td>103</td>
<td>4,00,000</td>
<td>3,25,000</td>
<td>1,85,470</td>
</tr>
<tr>
<td>Low cost poly house for vegetable production (100 m²/unit)</td>
<td>North Sikkim and Upper Subansiri</td>
<td>414</td>
<td>50.6</td>
<td>15500</td>
<td>36,750</td>
<td>19,625*</td>
</tr>
<tr>
<td>Nursery technology for mandarin (300 m²/unit)</td>
<td>North Sikkim and Upper Subansiri</td>
<td>12</td>
<td>5.5</td>
<td>60,000</td>
<td>2,00,000</td>
<td>1,35,000*</td>
</tr>
<tr>
<td>Integrated community-based service delivery system for small holders piggery development (2 F+1M/unit)</td>
<td>Mon</td>
<td>34</td>
<td>34</td>
<td>36,162</td>
<td>81,200</td>
<td>45,038*</td>
</tr>
<tr>
<td>Turmeric processing and value addition</td>
<td>Saiha</td>
<td>148</td>
<td>70</td>
<td>3,20,400</td>
<td>5,34,000</td>
<td>2,13,600</td>
</tr>
<tr>
<td>Organic ginger production</td>
<td>North Sikkim</td>
<td>160</td>
<td>16</td>
<td>80,000</td>
<td>5,56,000</td>
<td>4,50,000</td>
</tr>
<tr>
<td>Large cardamom sucker multiplication nursery</td>
<td>North Sikkim</td>
<td>263</td>
<td>117</td>
<td>2,12,875</td>
<td>6,62,500</td>
<td>3,49,625</td>
</tr>
</tbody>
</table>

*Economics computed on unit basis as per 2013-14 price

Some of the potential farming systems of the region are discussed below:

**Dairy based system**

Land up to 100% slope (45°) with a minimum of 0.5m soil depth may be utilized for livestock farming. Contour trenches and grassed waterways are the minimum requirements for land treatment. Cost of land development for such land uses may vary between 150 and 335 man days/ha. Such land use is expected to retain over 90% of annual rainfall and restrict the soil loss within 2 tones/ha/yr. Selection of leguminous and non-leguminous annuals and perennials, shrubs and trees will depend on the type of enterprises (such as milk, beef, mutton, wool, pork and poultry production). The fodder production has to ensure stability in fertility status of soil, availing the moisture supply towards maximum fodder production for longer period during the year and conservation of fodder for lean season. Annual legumes develop 100% canopy within 45 days of the onset of rains. Combination of cultivated varieties of perennial legumes, grasses, shrubs and trees can extend availability of green fodder up to February at low altitude thereby shortening the requirement of conserved fodder for lean season. Carrying capacity of such high land use has been estimated to be 4 to 5 livestock/unit/ha with setaria and stylo (1:1) mixture of fodder production. Livestock-based farming has potential for substantial income from the farmyard manure and self-sufficient in the matter of fuel through biogas plants. A dairy-based farming system model was developed on 0.94 ha hillock land having 32.02% slope falling under class Vle VIIe capability classification. Soil
and water conservation measures and crop combination have been planned to derive maximum advantages out of available natural resources (soil, water and human) of the area. After development, the area under terraces was 0.225 ha, risers 0.47 ha, trenches 0.095 ha, bunds 0.013 ha and rock 0.14 ha. Use of contour trenches at 1.5 m vertical intervals was adopted as a conservation aid for retaining water within the area. A total number of 335 man-days were engaged for trenched and land development.

Crops namely teosinte, cowpea maize and fodder turnips were grown in the first year. During the first year, 12.78 ton/ha green fodder was produced which was estimated to be enough to produce 228.6 kg of beef or 229.78 kg of mutton. The carrying capacity of land as estimated on the basis of the first year’s performance of fodder crop was worked out to be 1.24 cattle and 12.78 goat units per ha respectively. The actual requirement of the man-days per ha was as high as 574.9 against the available standard norms of 198.0 man days only. This wide gap has to be narrowed down with the introduction of efficient farm tools and implements. In the second year yield potential of yellow maize, oat, groundnut, tapioca and perennial fodder was recorded as 0.7, 0.6, 1.5, 17.1 and 13.5 ton per ha respectively. Out of 381 man-days per ha required for maintaining the land use 63.7 % efforts were needed to produce concentrated crops. In the 3rd year among annuals, soybean, maize, teosinte, groundnut and tapioca were grown in kharif season. Perennial fodder in 38 bunds yielded 44.70 kg green feed which was equivalent to 11.99 ± 3.2 ton per ha as compared to 11.87 ± 4.8 ton during the second year. The yield in terms of livestock feed was considered satisfactory because this could meet 78% fodder requirement of one cow (40 kg), two calves (60 kg), 6 pigs (30 kg) and 30 rabbits. In the fourth year, on an average, a total of 12.0 tonne green fodder and 1.0 tonne of concentrate were produced from the operational area of 0.54 ha with an average production potential of 1.1- 1.7 tonne /ha grain from maize and green fodder to the tune of 30.0, 28.0, 20.5, 20.0, 17.0 and 17.2 tonne /ha from guinea, love grass, setaria grasses, stylosynthes, napier bajra and maize, respectively. The cow yielding 10 litres of milk /day produced 3000 litres of milk. On an average input of Rs. 79.05/day (concentrate 3 kg, green fodder 50 kg labour 3 man hours and other expenses Rs. 5.50) yielded the output from the cow as Rs. 132.85 /day (milk and manure). Body weight gain of male and female calves was 166 and 115 kg. Input and output data showed a poor return on these stall-fed animals (Rs. 2232 and 2270 for she calf and Rs. 2317 and Rs. 3000 for he calf) Beef animals proved to be more profitable when maintained on pasture. Egg production was severely affected when layer mash was replaced by more than 5% green. Total 20 birds laid only 368 eggs in 4 months. Production of green fodder from the system during the system during the last five years varied from 13.7 to 72.0 tonne/ha/year. Concentrate production from the system can meet about 90 % requirement of ruminants and 80% of poultry. The animal unit comprised of two cows, one male calf, and one heifer.

Guinea, setaria and fodder crops; tapioca, maize, bajra and oat were grown in the 5th year. The yield of green fodder from terraces was 3.5 tonne and that of grasses from
risers was 137.4 q. Tapioca sown in trenches yielded 1.02 tonne on fresh basis. A total 323 saplings of *Ficus hookerii* were planted on the boundaries of watershed in the sixth year. The milk yield from a single cow was 1730 lit in the 1st year with concentrate consumption at the rate of 2.0 kg/day. In the seventh year, the area under terrace (0.225 ha) was put under two *kharif* crops of maize grain (March-July) and maize + rice-bean (Aug – Oct) fodder followed by *rabi* fodder crops of oat. Riser area is 0.47 ha. And area under bunds (0.013 ha) was under perennial fodder crops. The risers and bund area (0.483 ha) produced 21.1 tonne green fodder of setaria and guinea grass. Whereas the total green fodder utilized from terraces was 30.24q. The output ratio of the watershed during the 6th year was 1:1.35. In the top portion, broom grass was planted in the eighth year for forage in the lean winter month. The input out ratio of the watershed for the 8th year and 9th were 1:2.84 and 1:2.08 respectively. Excess fodder produced during the monsoon season was used as hay and paddy straw treated with 4% urea and leaves of broom grass were fed to cattle (two milch cow and two followers) maintained from November to May.

The average production of milk was 7.47 lit/day/cow. The dairy-based farming system has the potential for substantial return 1:1.78 from the farmyard manure and self-sufficiency in the matter of fuel through biogas plant 90% of annual rainfall retain in the watershed and restrict the soil loss 2 tonnes/ha/year. The carrying capacity of the land use was estimated as 4-5 livestock unit/ha.

**Agro-pastoral based land use**

The system can be adopted on hill slope up to 50% where the soil is more than 1 m. Bench terraces and contour bunding are the major soil conservation measures: Land development under the system may cost about 400 man days/ha. Selection of the crop should be based on farmer’s choice as well as market potentials. Hilltops should be kept under forest (fuel-cum-fodder trees, bamboo and timber trees etc.) Based on the existing farming systems, agroclimatic and soil conditions, the cropping systems are visualized are Rice-based cropping system (Rice-mustard/potato/radish), oilseed-based cropping systems etc. Cultivation of crops in toposequences is useful on hill slopes. Normally rice is taken in the bottom and cassava, buckwheat etc. grown on the upper terraces. Maize is grown next to rice. A dairy cow can be effectively integrated with crop production on terraced hill slopes for sustainable agriculture under the system. The by-product of crops and fodder raised on bunds and terrace raisers occupying about 30% of land provide scope for the subsidiary source of income through animal husbandry. Among perennial grasses and legumes – *Setaria* sp., thin *Napier*, Guinea and *Stylosanthes* were found good for terrace risers. Management of forage crops on the terrace risers is important. They should not be allowed to grow more than 50 to 60 cm tall to avoid any shade to food crops on the terraces. On the wide terraces, fodder trees can be planted. The deficit green fodder during winter can be met by feeding leaves of broom grass and crops residues produced in the watershed. Such an agro-pastoral land use has a potential of
maintaining 1.18 livestock unit (one unit equal 1.0 buffalo, 1.25 cattle, 5.0 pigs and 10.0 goats). In situ generation of farmyard manure from livestock refuse, weeds and non-edible crops residues can be effectively utilized under integrated nutrient management to reduce the chemical fertilizers requirements. Analysis of sustainability and livelihood potential showed that the system incorporates the classical organic recycling and noncompetitive inputs, arresting nutrients in rainwater flow by growing forage crops on the terrace risers, negligible soil erosion and converting in a chain all biomass produced in the watershed into economic outputs.

**Agri-horti-silvipastoral land use**

Land up to 100% slope with soil depth greater than 1 metre can be used for this mixed land-use system. The systems comprise agricultural land use towards the foot-hills, horticulture in the mid portion of the hill and silvi-pastoral crops in the top portion of hill slopes. Contour bunds, bench terraces, half-moon terraces, grassed ways are the major conservation measures. Land development may cost about 190 man days/ha. Such land uses are expected to retain over 90% of the annual rainfall with negligible soil erosion. This is the ideal system suited to steep hill slope. Variety of agricultural, horticultural and silvi-pastoral crops mentioned in the three systems can be grown in this system. Choice of crops will vary according to altitudes. The fodder from terrace risers, horticultural portion and the silvi-pastoral unit can sustain a unit of 10 goats with reproduction efficiency of 170% and the pigs can meet part of their nutrients requirement through succulent grasses, grains and radish produced in the watershed. The diverse agro-activities would help in producing most of the produce that remote area farmers would like to grow for their self-sufficiency in a highly remote place of the hills. This is an integrated system of farming and capable of providing full time and effective employment to a tribal family.

A model on micro watershed-based named Agri-Horti-Silvi Pastoral System was established in the year 1984 on 1.58 ha land at ICAR Research Complex for NEH Region, Umiam, Meghalaya. The area under planned land use is 1.03 ha and remaining 0.55 ha is under forest. The soil was clay loam having 41.77% slope, comes under VIIe land capability classification. The system comprises agricultural land use towards the foothills (0.2ha land), horticulture in the middle portion (0.29 ha land) and silvi-pastoral crops on the top of the hills (0.44 ha land). The distribution of the area was on the basis of water requirements, soil condition, depth of the soil and slope of the land. Conservation measures namely bench terraces at 1.0 m vertical and stilling basin (small water pools) and contour bunds in the middle and upper portion, for horticultural and silvi-pastoral crops, respectively, were used. A total number of 187 man-days were engaged for developments of land i.e. for contour bunding, terracing etc. On the terraces 0.20-hectare land in the foothills developed by bench terracing and contour bunding at 1 m vertical interval. The crops like maize, groundnut, ginger, rice bean and sweet potato in
kharif season and toria, radish, pea and turnip in rabi season were grown and found most suitable at 1000 m altitude.

The fruit crops like mandarin, guava, Assam lemon and pineapple in a double row on contour bunds have been planted on the middle portion on 0.29 hectare land in June – July 1984. Guava performs better as compared to mandarin and Assam lemon. Guava starts fruiting two and half years after planting and fast canopy developed. Pineapple planted in interspecies produce 409 no. of fruits in the year 1998. After 7 years of planting, size of fruits become smaller as compared to previous years in the system as a ratoon crop. Guava reached its full bearing stage after 7 years of planting and covered 90% of the area followed by Assam lemon. The growth of the orange was slow, 25% plants start flowering after 7 years of planting but no fruiting. The average productivity of guava after 8 years was 36.7 kg/tree, Assam lemon 48.3 nos./tree. After 11 years of planting, an average number of fruit/tree of orange and Assam lemon was 83.4 and 40.5 respectively. In the 11th year, average no. of fruits per tree of orange and Assam lemon 83.4 and 40.50 respectively showed good performance. In the 13th year, average no. of fruit per tree or orange and Assam lemon 91.7 & 37.6 respectively, the performance of orange was better over the last year. While, in the 14th year, average no. of fruits per tree of orange was reduced (76.5 nos./tree) whereas the yield of Assam lemon was not declined (36.9 nos./tree).

Alder (Alnus nepalensis) as a silvi component and broom grass as a herbaceous (pastoral) component showed better compatibility and growth performance. Broom grass as a pastoral component produced 1.75 tonne fresh and 0.77 tonne/ha dry weight of spikes. Leaves of broom grass were sufficient to feed a unit of 10 goats during lean winter month. All the crop production operations were managed through manual labour input requiring 619.8 man days as against the standard norms of 437.5 man days. Wheel hoe, V-blade attachment was found to save nearly 91.81% in man hour’s requirement for weeding of the crop planted in rows as compared to the other weeders. By adopting the soil and water conservation measures viz. Bench terracing, contour bunds, stilling basin and grassed waterways developed with the use of local resources was satisfactory, retaining 97% of the annual rainfall within the system. A unit of 10 goats and 10 pigs were maintained on grasses (broom grasses produced in the silvi-pastoral portion and guinea grasses in the horticulture portion and on the terrace risers of the agriculture portion), crop byproduct and radish and sweet potato produced in the system. The Khasi local pigs attained a growth rate of 138g/day, F1 hybrid (cross of local and Hampshire) 252g/day and F2 (Cross of local and Hampshire) 176g/day. F1 hybrid was most economical breed after 12 months of feeding. Land up to 100% hill slope with soil depth greater than 1 m can be used for this mixed land use system for the farmers living in remote areas and requiring all the basic needs.
**Alley cropping/Hedge row intercropping**

It is a type of intercropping where arable crops are grown in between the alleys (interspace) formed by the two hedgerows or leguminous shrub rows. It is also called as hedgerow intercropping. Depending upon the slopes, plant species involved, the alley width may vary from 2-5 m. In North East India, leguminous shrubs like Crotolaria, Tephrosia, Casia, Acacia, Cajanus cajan, Flemingia, Indigofera spp. etc. are suitable as alley crop or hedge row crop. Ginger, turmeric, maize etc are grown in between the alley. The alley height is generally maintained at about 1 m by pruning periodically and the pruned biomass is either used as mulch or incorporated into the soil as a source of nutrients. Intercropping in interspaces of hedgerow is a proven and sustainable technology for the NEH Region. The hedgerow grown in the contours helps in developing natural terrace in few years’ time. The green biomass (leaf, twigs etc.) of such hedgerow species are very rich in essential nutrients especially N, P and K. The nutrient content of some important hedgerow species are given in Table 4. This system of cultivation reduces erosion and conserves soil moisture and nutrients. On an average, pruning of N fixing hedgerow species added 20-80, 3-4 and 8-38 kg/ha/year of N, P and K, respectively. Addition of leaf biomass from hedgerow species resulted in a significant improvement in fertility status of soil (Laxminarayan *et. al.*, 2006).

**Table 4: Production of total pruned biomass and nutrient content in different hedge-row species**

<table>
<thead>
<tr>
<th>Hedge species</th>
<th>Total pruned biomass (per cent)</th>
<th>Nutrient concentration in green biomass (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. cajan</td>
<td>8.94</td>
<td>N 3.29 P 0.67 K 1.43</td>
</tr>
<tr>
<td>C. tetragona</td>
<td>19.55</td>
<td>N 3.47 P 0.48 K 1.63</td>
</tr>
<tr>
<td>D. rensonii</td>
<td>7.06</td>
<td>N 3.63 P 0.48 K 1.56</td>
</tr>
<tr>
<td>F. macrophylla</td>
<td>4.70</td>
<td>N 3.23 P 0.45 K 1.26</td>
</tr>
<tr>
<td>I. tinctoria</td>
<td>12.02</td>
<td>N 3.83 P 0.81 K 1.63</td>
</tr>
<tr>
<td>T. candida</td>
<td>10.86</td>
<td>N 3.57 P 0.32 K 1.67</td>
</tr>
</tbody>
</table>

*Source: Bhatt and Bujarbaruah (2005)*

The similar concept has been also tested under lowland condition for in-situ biomass generation for soil fertility management and to reduce dependence on external inputs like fertilizer. Hedge row species like *Tephrossia spp*, *Cajanus cajan* etc were grown on the alternate raised bunds in low land rice field. A good amount of biomass has been generated to supplement nutrient requirement of rice crops.

**Watershed approach in farming system**

Watershed as a tool for soil and water conservation measures as well as for the socio-economic development of a community is already a widely accepted fact. ICAR Research Complex for NEH Region, Umiam, Meghalaya has adopted 18 watersheds in different states of the NEH Region. To mention a few successful watershed are the Mawlangkhar watershed, West Khasi Hills, Meghalaya, Mawpun, Ri-Bhoi, Meghalaya, Jalukie, Nagaland. Through these watersheds, the Institute has taken the important technologies developed
by the Institute in the farmer’s field. The components of these watersheds includes, socio-economic survey for analysis of resource status, water harvesting structures, construction of bench and half-moon terraces along with other agronomic measures for soil and water conservations, introduction of HYV crops, introduction of fruits/vegetables, introduction of improved milch cow, pigs and rabbits, poultry and duckery unit, composite fish culture, small processing units, training on crop production and animal husbandry, interface meeting with NABARD, state agricultural officials, ICAR scientists and farmers were arranged.

The Jalkund (a micro rain water harvesting structure) technology was developed at the ICAR Research farm, Umiam and validated at farmer’s field. The steps for making Jalkund are digging a 5 x 4x 1.5 m pit (storage capacity 30,000 l) leveling the sides and corner of jalkund, smothered of walls of jalkund by plastering with mixture of clay and cow dung in the ratio of 5:1, cushioning of jalkund with dry pine leaf/hardy grass etc. @ 2 to 3 kg/m² and finally laying out LDPE Agrifilm (250µ) for covering the jalkund. The stored water stored should be covered to avoid the evaporation loss of water particularly during off season (November to March). Covering of Jalkund with thatch (5 – 8 cm thick) made of locally available bamboo and grasses reduce about 75 to 80 % evaporation loss of water. The use of neem oil @ 10 ml Jalkund over water surface after each weekly watering is also effective to minimize the evaporation loss of the water. 111 such jalkund were provided to farmers in four states (Meghalaya, Manipur, Nagaland and Tripura) of NEH region. All the Jalkunds are already functional and farmers are using the harvested water for diversified purposes. Farmers have modified the Jalkund in their own way. To mention a few one, some have given tent (Tirpal) covering, some even given GI sheet roof, some are using siphoning to collect water while others are using plastic buckets. In Ri-Bhoi, few farmers are growing strawberry at stored water. Most of the farmers at the upper ridges are using stored water for livestock components. Farmers at Mawlangkhar, used barbed wire to fence the Jalkund and using the water for Livestock, vegetable production as well as for domestic purposes. The feedback from farmer’s field indicated that the water stored in a jalkund is sufficient for irrigating 200 tomato plants, rear 5 piglets, two ducks or 50 poultry birds during the dry season of November to March.

The cost of one Jalkund was calculated at Rs. 8020. However, if family labour is engaged then expenditure on digging, plastering, cushioning, etc., could be saved, then only a total of Rs. 6000 would be sufficient for one Jalkund. The cost of per litre store water in the first year was calculated at Rs. 0.2 considering the average life of lining material at 3 years, the cost per litre stored water reduced to Rs. 0.067 only. In Ri-Bhoi tomato-poultry was found most economical with a B: C ratio of 1.71 followed by tomato-pig (1.67).

Integrated Organic Farming Farming system

Integrated Organic Farming System (IOFS) is an innovative concept of on-farm resource management strategy to achieve economic and sustained agricultural production to meet the diverse requirement of the farm household while preserving the resource base.
and maintaining high environmental quality. Components of IOFS when carefully chosen and executed depending upon the suitability of the farm fulfills the input demand internally and totally avoids the purchase of any external inputs. This will not only help to reduce the production costs but also enhances the quality and quantity of produce and improves environmental quality through recycling of organic wastes.

The IOFS model for valley land (950 m above mean sea level) comprising different enterprises such as cereals (rice and maize), pulses (lentil, pea), oilseeds (soybean, rapeseed), vegetable crops (French bean, tomato, carrot, okra, brinjal, cabbage, potato, broccoli, cauliflower, chili, coriander, etc.), fruits (Assam lemon, papaya, peach), dairy unit (a milch cow + calf), fodder crops, central farm pond, farmyard manure pits and vermicomposting unit have been developed (0.43 ha) at ICAR Research Complex for NEH Region, Umiam, Meghalaya (950 m altitude) since 2005 under Institute programme and later standardized under Network Project on Organic Farming, funded by ICAR-Indian Institute of Farming System Research since 2012. A farm pond of 460 m² area with an average depth of 1.5 m was part of the IOFS model for life-saving irrigation and aquaculture. Climbing vegetables such as bottle gourd, chow-chow, cucumber, ridge gourd etc., were grown on a structure created above water bodies on one side of the pond dyke for vertical intensification. Pumpkin was raised in another side of the pond and allowed to crawl on the ground/pond dyke slopes. The washings from the dairy unit were diverted to fish pond for promoting the growth of zooplankton and phytoplankton for fish growth. The solid waste from cowshed was used for FYM making and vermicomposting.

The total cost of cultivation was recorded at Rs. 55,839/- per year under the IOFS model with an area of 0.43 ha. Maximum expenditure was incurred in crop component of the model with 48% of the total cost of cultivation. Dairy unit with one adult cow and one calf registered 36 % of the total cost of cultivation, while fishery component recorded 9% of the total cost of cultivation. For maintaining vermicomposting unit of 72 m² area and other important operations like hedgerow planting, residue recycling, rock phosphate application and liming, the expenditure incurred was Rs. 3700/- which account for 7% of the total cost. Since the soil of the northeast India and study site is acidic in nature, application of rock phosphate (100-150 kg/ha) and liming (500 kg/ha in-furrow in alternate years) is required for phosphorus nutrition as the application of organic manure alone is not enough to meet the crop requirement. A total net return of Rs. 62,531/- per year was achieved under the IOFS model which is much higher than the region's farmer common practices of rice mono-cropping or improved practice of rice-vegetables cropping system. The highest contribution towards the total net return was contributed by crop component of the model (61%) followed by dairy (25%) and fishery component (20%). The fish production was 136 kg. The net return from dairy component was calculated only in terms of milk production since the cow-dung produced was recycled back into the model which was used as manure for crop production. The production of
vermin-compost from the model was 1500 kg annually and it was used in the farm itself for the nutrient supplement to crops.

For 0.43 ha area, the total nutrient requirement for organic crop production has been estimated at nitrogen (N) 64.7 kg, phosphorus (P₂O₅) 23.1 kg and potassium (K₂O) 53.8 kg. On-farm nutrient recycling in IFOS could produce an amount of 59.7 kg N, 18.9 kg P₂O₅ and 51.9 K₂O. Hence, 92% of the total N requirement, 82% of the total P₂O₅ requirement and 96% of the total K₂O requirement could be met within the model itself and only 8% of the total N requirement, 18 % of the total P₂O₅ requirement and 4 % of the total K₂O requirement is required to be met from the external source to sustain the model. The nutrient requirement of the model from an external source would be reduced substantially with the efficient recycling of pond silt, intercropping with a legume, use of biofertilizers such as Azotobacter, Rhizobium, phosphorus solubilizing microorganism etc.

Considering the benefits from the IOFS model with a net return of Rs. 62531/- per year (Rs. 5211/month) from 0.43 hectare area, a net income of Rs. 5100/- per month or Rs. 174/- per day was achieved which is a modest amount for living by a four-member family (2 adults and 2 children). Assuming food requirement and other expenditure per day for a four-member family (2 adults and 2 children) for rice (1300 g, Rs. 33), dal (150 g, Rs. 15), oil (300 g, Rs.15), vegetables (1000 g, Rs. 25), fruits (400 g, Rs. 20,), fish (110 g, Rs.17), meat (100g, Rs.15), others (milk, egg etc. Rs. 15), a total of Rs. 155 is required per day towards food. However, there is further need to enhance the income to meet the other requirement of the family i.e. healthcare, schooling, clothing etc.

**Adaptation to climate change: micro options with farmers**

In the absence of adequate vulnerability assessment which is the key requirement to know the possible impact of climate change and implements adaptation strategies and policies, following strategies may be adopted in an integrated farming system approach for the North East India. These practices conserve natural resources, effectively utilizes local resources, increases farmers’ income and maintains balance in ecosystems. Some of such options are-

- Altering sowing time/agronomic practices to cope up with changes in climate
- Switching cropping sequences/ changing varieties/crops to suit current climate situation.
- Water harvesting – Watershed approach, *Jalkund* (micro-rain water harvesting structure for hills), roof water harvesting for life saving irrigation,
- Diversifying income through integrated farming systems to reduce climate risks
- Devising location specific technologies and recycling on-farm biomass and resources
- Improving *jhuming* by incorporating soil and water conservation measures, improved varieties and agronomic practices.
- System of rice intensification, integrated crop management, no-till along with residue retention, inclusion of legumes in farming practices will enhance resilient of farming and reduce risk against climate anomalies.
• Location-specific contingency planning and preparedness are required for climate resilient agriculture.
• In farming system, traditional fruits and vegetables may be included for providing resilience to the system.
• Promotion of secondary agriculture and post-harvest processing
• Emphasis on perennial component like MPTs, fruits, livestock etc.
• Governmental and institutional policies and programmes

Conclusion

Location-specific integrated farming system (IFS) is the most effective way of natural resource management and reducing the impact of climate change for small and marginal farmers of North East India. Under IFS a number of crop and animal enterprises are integrated depending upon the available resources and demand in the region. The waste of one component serves as input for other component and reduces the requirement for external resources. The productivity of all the components are higher than their individual performance and farmers gets maximum benefit due to the reduction in the cost of cultivation. Since a number of components are combined the farmer remained engaged throughout the year i.e. the IFS increases the employment at farm level and hence, make the farming resilient to climate anomalies due to better income. Farmer’s gets the crop, vegetables, protein from meat, pulses etc., and therefore increases the food and nutritional security. The water harvesting is the central activity of any farming system. Lifesaving irrigation is given from the harvested water. The development of appropriate crop calendar depending upon the resources available is the key to success of any farming system. Depending upon the land, soil type, rainfall, resources available with the farmers and local demand appropriate combination of enterprises should be selected. Under NE condition, farm pond for aquaculture, piggery, duckery along with crop, vegetables and fruits are feasible options.

References


Significance of soil health card and strategies for improving acid soil quality and input use efficiency in NEH region

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‘Soil health’, has in recent years, become associated with sustainability in agriculture. ‘Soil health’, is invariably interchanged with the term ‘soil quality’. The soil health refers to self-regulation, stability, resilience, and lack of stress symptoms in a soil as an ecosystem. Soil health describes the capacity of a soil to function and it is the biological integrity of the soil community viz., the balance among organisms within a soil and between soil organisms and their environment”.

‘Soil quality’ is a term that more often is used to describe physical attributes of a soil. As a result, any attempt to promote practices which lead to improved soil health must be linked directly to improved economically viable production from a field.

Healthy soils are high performing, productive, reduce production costs and improve profits. Besides these direct effects, healthy soils hold more water and losses less water through runoff and evaporation thereby acts as the buffer in climate-sensitive situation.

As soil scientists and agronomists working with nutrient management, we are all well aware that most of the biological, chemical and physical properties we attribute to improved soil health come from the maintenance or improvement of soil organic matter. Soil organic matter helps to improve soil tilth, water infiltration and storage, CEC, microbial activity and macro, secondary and micronutrient availability.

Organic manures alone may not be able to meet the nutrient requirement of high yielding varieties of crops to produce the required food grains for the burgeoning human population due to their low nutrient contents and slow rates of nutrient release. Crop residue removal/burning in India is a serious problem, leading to widespread problems of secondary and micronutrient deficiency, explaining the “yield stagnation” scenario. The nutrient needs of crops and associated nutrient losses of Indian agriculture are so large (and growing each year) that no single source, be it inorganic fertilizers, organic manures, or crop residues can meet them by itself. Lecture delivered at the model training course on “Integrated farming system for Sustainable Hill Agriculture: An option for climate smart agriculture and NRM” during 24-31\textsuperscript{st} Oct. 2017 at ICAR Research Complex, Manipur Centre, Imphal, Manipur.

Indian soils are still estimated to be losing close to 9 million tonnes (MT) of N+P\textsubscript{2}O\textsubscript{5} +K\textsubscript{2}O (NPK) annually through crops even after harnessing currently utilizable organic resources plus input through BNF on a gross basis. It is projected that, in the year 2050, the food grain production (estimated at 457 MT) would remove about 58 million tonnes of NPK with an addition of 48 million tonnes of fertilizer nutrients. This would result in a negative gap of 10 million tonnes per annum of NPK. At present, the NPK consumption in India is 25.53 million tonnes. Thus, integrated use of the chemical, organic and biological sources...
of plant nutrients and their different management practices have a tremendous potential not only in sustaining agricultural productivity and soil health but also in meeting a part of chemical fertilizer requirement for different crops and cropping systems in India. The recycling of the huge quantity of organic wastes can bridge this gap and municipal solid wastes (MSW), because these can serve as valuable sources of plant nutrients if recycled in agriculture through proper technology. Similarly, a vast amount of human excreta is generated in the country but not recycled in proper manner to benefit agriculture.

The organic materials most commonly used to improve soil fertility include animal manures, composts (mixture of decomposed plant residues etc.), crop residues, urban organic wastes (either as such or composted), poultry manure, green manure, bio-gas spent slurry, vermicompost, agro-industrial wastes (oilseed cakes, press mud cake, rice husk and biomass ashes), residues from processing of animal products (blood, horn-and bone-meal), etc.

In India, out of 980 Mt of solid wastes being produced annually, around 350Mt are organic wastes generated from agricultural wastes. The total nutrient (NPK) potential of various organic resources was estimated at 14.85 Mt in 2000, which would become around 32.41 Mt by 2025. The total MSW generated by urban India is estimated to be 188,500 t per day (or 68.8 Mt per year). About 8.9 Mt of press mud cake and 12.1 Mt of poultry manure are available annually in India. It is estimated that 5-14 Mt of compost can be prepared from MSW depending upon the method of composting.

Management strategies
Soil health management needs a system of practices like use of plant diversity to increase diversity in the soil, follow minimum tillage principles, cover soils growing most part of the year and keep the soil covered as much as possible. Management strategy for organic sources is to optimize plant nutrient recovery and to minimize pollution, particularly from N and P, and other constituents.

The agronomic value of organic manures as fertilizer is determined by their ability to increase the yield or quality of crops. Crop yield responses to addition of organic materials are highly variable and are dependent upon the crop, soil type, climatic conditions, management practices and the quality of the organic manure used. Organic manures decompose or mineralize in soil at variable rates.

Long-term trials showed that well managed, high yield cropping systems, which return crop residues to the field, do improve soil organic matter and related soil biological, chemical and physical properties. Work with conservation tillage and nutrient management further indicates that not only is soil organic matter improved, but the system can support current or higher yields, and reduce associated GHG emissions per tonne of grain production.
They do, however, have a greater residual effect on soil fertility than chemical fertilizers, because of slow release of nutrients. Application of organic manures generally increases crop yields above those of fertilizers alone.

Many factors contribute to soil quality or health. Favorable physical factors such as texture are an important component of quality but texture is largely unchangeable. The key factor in quality is the SOM fraction, which although relatively small, has a strong influence on the overall wellbeing of the soil and its beneficial functions. Soil organic matter controls soil microbial populations and their many functions in soil such as decomposition and nutrient cycling.

Fertilizer use can have positive or negative effects on soil health. Depending on the tillage system used, regular additions of N fertilizer can enhance SOM levels. Organic matter can help increase soil aggregate stability and thus contribute to resistance to erosion and soil degradation.

The extent to which mineral fertilizers can contribute to economic and efficient crop production, and concomitantly benefit the soil in terms of quality or health, is dictated by the adoption of best management practices. These principles call for the integrated use of organic manures with mineral fertilizers whenever possible. As with many other areas of science, there needs to be a more concerted effort to educate the public at large on the synergy between fertilizers in relation to crop yields and quality or health of the soil. Soil and agronomic research has clearly shown that that sustainable agricultural intensification and a healthy environment are compatible goals.

Assessment of soil health quantitatively is the most challenging task for the soil scientists. Since the time of Justus Von Liebig in the later part of nineteenth century, the agricultural chemists all over the world have been making concerted efforts to develop methods to measure soil health. Several of the analytical methods developed by the scientists from 1930 onwards have been very useful in measuring the available nutrients status of soils, which is a component of soil health. These methods are being adopted extensively in the soil testing laboratories being functional at the district headquarters all over the country.

The soil samples are being collected from farmer’s fields by officials of the agricultural department and sent to the laboratory for analysis. After analysis the soil health card is prepared giving details about the available nutrients status of soil, organic matter status, soil reaction and salt content. Based on the results, the quantity of NPK fertilizers to be added for a crop would be recommended. Also, the quantity of amendments, if required to be added will be indicated. This soil health card serves as a guideline to farmer for maintaining the soil health.

Since the available nutrients status of soil would fluctuate depending on the crops grown and the nutrient management practices adopted, it is customary to do the soil testing once in 4 to 5 years under single cropped areas and once in 2 to 3 years in double cropped areas.
Acid soils are base unsaturated soils which have enough of the adsorbed exchangeable hydrogen ions (H+) to give a pH value less than 7. These are generally developed in high rainfall areas (Humid regions). In India, acid soils (pH <6.5) occupy about 90 million hectares (34% of the total cultivated area) and NEH region alone has nearly 20 million hectares of acid soils.

The acid soils usually possess high proportion of exchangeable H+ and Al3+ ions, low in exchangeable bases (< 70 % base saturation) and low CEC. They exhibit toxicity of iron, manganese and aluminum but deficiency of phosphorus, calcium, magnesium and boron. They are mainly formed due to leaching of bases in high rainfall and in areas having acidic parent materials. Also, they are formed due to faulty nutrient management practices i.e. continuous use of acid forming fertilizers like ammonium sulphate, urea, etc. The productivity of crops in these leached /bleached acidic soils is much low because of multi-nutrient deficiencies coupled with toxicity of iron, manganese and aluminum.

Since the livelihood, security of the entire population living in these NEH states is at stake because of acidic soils and their low productivity, the only option is to go for improving the quality of acid soils through appropriate management practices suitable for the region.

**Some of the management practices, which can be adopted, are listed below:**

1) Amelioration/correction of soil acidity through liming.
2) Adoption of soil conservation measures to prevent soil erosion.
3) Breeding/screening of varieties having tolerance to soil acidity.
4) Balanced application of nutrients based on soil test results.
5) Use of rock phosphate along with single super phosphate in 3:1 ratio along with judicious use of organic manures.
6) Use of biofertilizers to enhance use of efficiency of phosphatic fertilizers.
Organic farming based integrated farming system and opportunities of sustainable entrepreneurship development

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Introduction
Organic agriculture offers the most sustainable solution for developing the agricultural sector and provides food security with least negative impacts on the environment and also offers solutions for sound rural development, provides healthy food and creates jobs. The demand for organic produce is very high hence cost of organic products is 2–3 times higher than the conventional ones depending on the products and area. India’s rank in World’s Organic Agricultural land is 15 (www.ifoam.org) with 5.71 Mha area under organic certification (2015-16). This includes 26 per cent cultivable area with 1.49 Mha and rests 74 per cent (4.22 Mha) forest and wild area for collection of minor forest produce (www.apeda.org). The organic food production in Asian countries is mainly for the export market as the domestic consumption is still emerging (IFOAM, 2004). Organic agriculture avoids nutrient exploitation and increases soil organic matter content. In consequence, soils under organic farming capture and store more water than soils under conventional cultivation. Furthermore, organic farming reduces the vulnerability of the farmers to climate change and variability by comprising highly diverse farming systems and thus increases the diversity of income sources and the flexibility to cope with adverse effects of climate change and variability, such as changed rainfall patterns.

Organic agriculture offers the most sustainable solution for developing the agricultural sector and provides food security with least negative impacts on the environment and also offers solutions for sound rural development, provides healthy food and creates jobs. Organic farming is a method of farming system is the use of organic wastes (crop, animal and farm wastes, aquatic wastes) and other biological materials, mostly produced in situ along with beneficial microbes (biofertilizers) to release nutrients to crops, which means the ‘organic’ nature of organic farming. Integrated farming system is the integration of various farming components in complimentary manner for improves over all farm income and resource use efficiency. When organic farming blended with the integrated farming system (IFS) approaches than becomes more meaningful and reduces the dependency on market inputs. The marginal and small farmers constitute 78.2 per cent of the farming community in India. The unique Indian situation of small fragmented holdings and lack of capital investments is not suitable for single commodity farming being practiced in developed countries. Therefore, the integrated farming system appears to be a viable solution to the Indian agriculture for increasing productivity and income of the small and marginal farmers with constrained resources. The concept of integrated farming can be adopted in any situational basis as it does not involve any particular pattern and it can be formulated as the facilities available and land type. Integrated farming system adoption can be better business opportunities for graduates.
as by better planning and provides employment for the rural population. It will be better enterprise option for women entrepreneur as it involves low cost and yields high income.

**Why agripreneurship:** During 1991 the new economic reforms were released, globalization gave way to seamless competition between the India and other countries of the world had to make a perfect stand for itself and Indian agriculture, being the backbone of the economy needed more attention. Indian agricultural products were demanded in foreign counties and their export could bring in profitable gain thus the need was felt for bringing the entrepreneurs of the country to finance their capital into agricultural sector. Hence, agricultural entrepreneurship is the need of the hour because today our economy consists of entrepreneurship in many sectors and then our farmers are in great use of assistance to entrepreneurs and can be of great help. Farming has seen a new phase since the entry of entrepreneurs because the entrepreneurs help to give farmers better yields for their product by using the agricultural products for manufacturing industries like milk and meat product through dairy, fruits juices through fruits, processed fish and chicken product through fishery and poultry. Entrepreneurs try to link the grain farmers to manufacturing industries so that they may get a better price for their produce.

There are so many reasons for developing agripreneurship, however some of those given hereunder.

1.  Shortening rural to urban migration
2.  Increasing the quality of agricultural products
3.  Bringing forward skill manpower
4.  Reduces unemployment and enhancing income

**What is Organic Farming?**

IFOAM defines “organic agriculture” as: “a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved.”

The International Federation of Organic Agriculture Movements (IFOAM) has formulated the following four broad principles of organic farming,

1. **Principle of Health:** Organic agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible. Health is the wholeness and integrity of living systems. It is not simply the absence of illness, but the maintenance of physical, mental, social and ecological well-being.

2. **Principle of Ecology:** Organic agriculture should attain ecological balance through the design of farming systems, establishment of habitats and maintenance of genetic and agricultural diversity. Those who produce, process, trade, or consume organic products
should protect and benefit the common environment including landscapes, climate, habitats, biodiversity, air and water.

3. **Principle of Fairness**: Organic agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities. Fairness is characterized by equity, respect, justice and stewardship of the shared world, both among people and in their relations to other living beings.

4. **Principles of Care**: Organic agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment. It should prevent significant risks by adopting appropriate technologies and rejecting unpredictable ones, such as genetic engineering.

**Integrated Farming System**

Farming system which integrates natural resources and regulation into farming activities to achieve maximum replacement of off-farm inputs secures sustainable production of high quality food and other products through ecologically preferred technologies, sustained farm income, reduction of sources of present environmental pollution generated by agriculture and sustains the multiple functions of agriculture. In another language, when different enterprises are dependent, complementary and supplementary to each other, they interact among themselves and affect the others. Such a mixed farming system is termed an “integrated farming system”

**Aims we can achieve through IFS**

- Efficient recycling of farm and animal waste
- Minimize the nutrient losses
- Maximize of the nutrient use efficiency
- Complementary combination of farm enterprises
- Increase the productivity and sustainability of the system
- Increase the profitability of the farm

**Possible complementary enterprises**

Crop production, Fruit production, Agro-forestry, Vegetable production, Ornamental flower, Seed production, Aromatic and medicinal plant, Post-harvest processing, Biogas production, Sericulture Dairy, Goat rearing, Sheep rearing, Poultry, Fish rearing, Rabbit farming, Apiaries, Duck farming, Quail production, Mushroom production, Piggery.

**Farming System Approach**: According to National policy for farmers, 2007 “Crop livestock integrated farming systems as well as agro processing is expected to increase productivity, efficiency of small farmers and would create multiple livelihood opportunities”.

1. Appropriate development concepts have to be elaborated and adjusted to the local conditions to meet the particular requirements of the farmers
2. Integrated Farming system can be regarded as a promising option to create additional cash-income and thus alleviate poverty, by an increase in productivity through a multiple use of farmland

3. The IFS approach is holistic, multidisciplinary, problem solving, location specific and farmer-oriented, and it treats agriculture as a complex interaction between natural and social phenomena

4. Integrated farming systems (IFS) approach serves as a good model for helping subsistence farmers achieve a reliable food supply, increased income, and greater environmental sustainability

**Basic criteria for assessing the sustainability of IFS models**

- Model should be self-input generating, means minimum requirement from the market.
- IFS Model should able to generate year round employment and income, means act as bank ATM.
- Waste of one component should be wealth for another component, means complementarity should exist between the various components.
- Model should be energy efficient, economically viable and socially acceptable.
- Rationality should maintain between, economic, ecological and social dimensions of IFS models
- IFS model should be capable to sustain the farm family need as per the ICMR recommendation.
- While designing the IFS Models, ecosystem services should take into consideration, model should effectively reduce the GHG emission, soil and nutrients erosion.

**IFS and Organic Farming**

Integrated farming system (IFS) is entire complex of development, management and allocation of resources as well as decisions and activities, within an operational farm unit, or combinations of units results in agricultural production and processing and marketing of the products. Whereas organic farming is a production system, which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators and livestock feed additives. To the maximum extent feasible, organic farming system relies on crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivations, mineral bearing rocks and aspect of biological pest control to maintain soil productivity and to supply plant nutrients and to control insects, weeds and other pests.

Integrated Farming System is a common sense whole farm management approach that combines the ecological care of a diverse and healthy environment with the economic demands of agriculture to ensure a continuing supply of wholesome, affordable food. It is a dynamic concept which must have the flexibility to be relevant on any farm, in any country, and it must always be receptive to change and technological advances. Above all, integrated farming system is a practical way forward for agriculture that will benefit all society, not just those who practice it. Organic farming aims for human welfare
without harming the environment and follows the principles of health, ecology, fairness and care for all including soil. The modern concept of organic farming combines the tradition, innovation and science. It has been reported that organic farming can minimize energy consumption by 30.7 per cent per unit of land by eliminating the energy required to manufacture synthetic fertilizers and pesticides and by using internal farm inputs, thus reducing fuel used for transportation. India can emerge as global leader with the presence of large number of organic producers (almost 7 lakh producers) and they need to be supported with technical knowledge and inputs, besides, marketing infrastructure. The research results available for little over a decade confirms the yield advantage in many crops such as basmati rice, maize, cotton, chickpea, soybean, groundnut etc.

**Objectives of IOFS (Organic Farming Based Integrated Farming System)**

Farming system is a complex inter-related matrix of soils, plants, animals, implements, labour and capital, inter-dependent farming enterprises.

- To develop farm - household systems of rural communities on a sustainable basis
- To improve efficiency in organic farm production
- To raise farm and family income
- To increase welfare of farm families and satisfy basic needs
- To reduce the dependency of farmers on off farm products and promote effective and judicious utilization of available resources.

**Benefits of IOFS**

- Consist income from various sources at any point of time during the year
- Minimization of risk due to subsidiary allocation to different enterprises in the event of unexpected failures of one component
- Increasing employment opportunity, energy and resource use efficiencies
- Ensuring the higher productivity per unit area
- Augmented returns and recycling of organics in complementary form
- Overall upliftment of farm
- Better allocation as well as utilization of inputs within the farm
- Create more ecosystem services

**Why Organic farming in IFS?**

Despite use of new and improved crop varieties and chemical fertilizers, crop yield began to slow down in the latter part of the 20th century. The world’s annual cereal yield growth rate has declined from an average of 2.2 percent in the 1970s to 1.1 percent in the 1990s (Gruhn et al. 2000). Thus, nutrient management through organic farming helps to stabilize soil fertility via improving nitrogen fixation and reducing nutrient leaching. Recently, soil condition has also been affected by climate change and an increase in the prevalence of severe weather events. There is a need for innovative farming solutions to improve soil health so that food production resilience may be ensured. The following have been identified as the main threats to soils in the soil strategy.
Soil organic matter decline reduces soil quality, affecting fertility, structure, water retention capacity, soil biodiversity and carbon storage.

Soil erosion can be accelerated by soil cultivation, leading to the loss of soil due to the action of water, tillage or wind.

Compaction by farm machinery leads to a decline in a soil’s capacity to retain water and supply oxygen to roots. This can lead to soil erosion, increased water runoff and GHG emissions.

Biodiversity decline (e.g. soil microbes and soil animals) is affected by all of the above and also climate change. Soil microbes benefit crop production because they decompose organic matter, release nutrients in a plant available form (e.g. nitrogen mineralization), stabilize soil structure and can control soil-borne pests and diseases.

Soil contamination with chemicals or pests and pathogens results when hazardous substances are either spilt or buried directly in the soil, or migrate to the soil from elsewhere.

**Organic food production through Farming system approach (Field experiences)**

**IOFS model for valley land**

The IOFS model comprising different enterprises such as cereals (rice and maize), pulses (lentil, pea), oilseeds (soybean, rapeseed), vegetable crops (French bean, tomato, carrot, okra, brinjal, cabbage, potato, broccoli, cauliflower, chili, coriander, etc.), fruits (Assam lemon, papaya, peach), dairy unit (a milch cow + calf), fodder crops, central farm pond, farmyard manure pits and vermicomposting unit. A farm pond of 460 m$^2$ area with average depth of 1.5 m was part of the IOFS model for life saving irrigation and aquaculture. Climbing vegetables such as bottle gourd, chow-chow, cucumber, ridge gourd etc., were grown on a structure created above water bodies on one side of the pond dyke for vertical intensification. Pumpkin was raised in another side of the pond and allowed to crawl on the ground. The washings from the dairy unit were diverted to fish pond for promoting growth of zooplankton and phytoplankton for fish growth. The solid waste from cow shed was used for FYM making and vermicomposting.

The total cost of cultivation was recorded at Rs. 55,839/- per year under the IOFS model with an area of 0.43 ha. Maximum expenditure was incurred in crop component of the model with 48% of the total cost of cultivation. Dairy unit with one adult cow and one calf registered 36 % of the total cost of cultivation, while fishery component recorded 9 % of the total cost of cultivation (Table.27). For maintaining vermicomposting unit of 72 m$^2$ area and other important operations like hedgerow planting, residue recycling, rock phosphate application and liming, the expenditure incurred was Rs. 3700/- which account for 7 % of the total cost. Since the soil of the northeast India and study site is acidic in nature, application of rock phosphate (100-150 kg/ha) and liming (500 kg/ha in furrow in alternate years) is required for phosphorus nutrition as application of organic manure alone is not enough to meet the crop requirement. A total net return of Rs. 62,531/- per year was achieved under the IOFS model which is much higher than the
region’s farmer common practices of rice monocropping or improved practice of rice-vegetables cropping system (Table 1). The highest contribution towards the total net return was contributed by crop component of the model (61%) followed by dairy (25%) and fishery component (20%). The fish production was 136 kg. The net return from dairy component was calculated only in terms of milk production since the cow dung produced was recycled back into the model which was used as manure for crop production. The production of vermicompost from model was 1500 kg annually and it was used in the farm itself for nutrient supplement to crops.

Table 1: Economics of the IOFS model (area=0.43 ha)

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Components</th>
<th>Area (ha)</th>
<th>Cost of cultivation/year (Rs)</th>
<th>Gross return/year (Rs)</th>
<th>Net return/year (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Crops</td>
<td>0.373</td>
<td>27129 (48%)</td>
<td>65370 (55%)</td>
<td>38241 (61%)</td>
</tr>
<tr>
<td>2</td>
<td>Dairy</td>
<td>0.004</td>
<td>20250 (36%)</td>
<td>36000 (30%)</td>
<td>15750 (25%)</td>
</tr>
<tr>
<td>3</td>
<td>Fishery</td>
<td>0.05</td>
<td>4760 (9 %)</td>
<td>17000 (14%)</td>
<td>12240 (20%)</td>
</tr>
<tr>
<td>4</td>
<td>Nutrient cycling</td>
<td>0.01</td>
<td>3700 (7%)</td>
<td>0</td>
<td>-3700 (-6%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>0.43</strong></td>
<td><strong>55839</strong></td>
<td><strong>118370</strong></td>
<td><strong>62531</strong></td>
</tr>
</tbody>
</table>

For 0.43 ha area, the total nutrient requirement for organic crop production has been estimated at nitrogen (N)-64.7 kg, phosphorus (P$_2$O$_5$) - 23.1 kg and potassium (K$_2$O)-53.8 kg. On farm nutrient recycling in IFOS could produce an amount of 59.7 kg N, 18.9 kg P$_2$O$_5$ and 51.9 K$_2$O. Hence, 92% of the total N requirement, 82% of the total P$_2$O$_5$ requirement and 96% of the total K$_2$O requirement could be met within the model itself and only 8% of the total N requirement, 18 % of the total P$_2$O$_5$ requirement and 4 % of the total K$_2$O requirement is required to be met from the external source to sustain the model. The nutrient requirement of the model from external source would be reduced substantially with the efficient recycling of pond silt, intercropping with legume, use of biofertilizers such as azotobacter, rhizobium, phosphorus solubilizing microorganism etc.
Integrated farming system model (1 ha area) for enhanced income and nutritional security

Different components of Integrated Farming System (IFS) was earmarked for one ha area in which 7000 sq m area was allotted to agri/vegetable based cropping system, 2000 sq m under horticulture and 500 sq m under water harvesting pond in which fish culture was started. Livestock sector was utilized under 500 sq m area where vermi-compost unit, threshing floor and miscellaneous uses were accommodated. Among the 7000 sq m area, 2300 sq m was allotted to rice-toria-french bean, 2500 sq m for maize based cropping system, 900 sq m under spice based cropping system, 600 sqm for groundnut based cropping system and 700 sq m under vegetable based cropping system.

1. Production and economic dynamics of various cropping system in IFS

Rice-toria-frenchbean system was allotted to 2300 sq m area which gives income of Rs. 47050.00 and income potential of Rs. 20.46/sq m. The maize based cropping system involving soybean, black gram, green gram, French bean, toria were planted in 2500 sq m which recorded income of Rs. 31,548.00 with income potential of Rs. 12.62/sq m. The spices crops were grown in 900 sq m area on which cucumber, bottle gourd, sponge gourd and squash were grown as vertical crop. The income from spice based cropping system was recorded to Rs. 7,7166.00 with income potential of Rs. 85.74/ sq m. The area under vegetable based cropping system registered 300% cropping intensity in 700 sq m area with income of Rs. 31,520.00 and income potential of Rs.45.03/ sq m. The lowest area 600 sq m, as well as, income amounted to Rs. 5250.00 was recorded from groundnut-toria cropping system.

Total income of Rs.1, 92,534.00 with income potential of Rs. 27.50/sq m was recorded from the whole system. Simultaneously, the highest yield (kg REY/sq m) of various cropping systems was recorded with turmeric + sponge gourd (8.32 kg/sq m) followed by turmeric + bottle gourd (7.07 kg/sq m) and turmeric + cucumber (6.43 kg/sq m). As a whole, the crop production unit registered yield of 13,964 kg REY from 7000 sq m gross cropped area.

2. Production and economic dynamics of fruit crops in IFS

The orchard component occupied an area of 2000 sq m in which four fruits species viz., Assam lemon, guava, peach and Khasi Mandarin were planted in an area of 270, 675, 335 and 720 sq m, respectively. The saplings of fruit plants were planted during 2010. On the terrace riser in fruit orchard, shrubs, legume seed (*Tephrosia* sp.) were sown for the site stabilization and in-situ fertility management. The height and diameter of fruit plants were presented in Table 2 which revealed that peach and guava had attained more height and diameter while orange was shortest one having plant height of 102.0 cm with plant diameter of 10.50 cm at 30 cm above the ground.
Table 2: Planting details and growth attributes of fruit plant

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Fruit species</th>
<th>Area (m²)</th>
<th>No. of plants</th>
<th>Date of planting</th>
<th>Plant height (cm)</th>
<th>Plant diameter (cm)</th>
<th>Production (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Assam lemon</td>
<td>270</td>
<td>30</td>
<td>22.07.10</td>
<td>158.1</td>
<td>6.45</td>
<td>-</td>
</tr>
<tr>
<td>2.</td>
<td>Guava</td>
<td>675</td>
<td>75</td>
<td>07.07.10</td>
<td>317.0</td>
<td>17.42</td>
<td>380</td>
</tr>
<tr>
<td>3.</td>
<td>Peach</td>
<td>335</td>
<td>37</td>
<td>24.02.11</td>
<td>318.8</td>
<td>16.83</td>
<td>-</td>
</tr>
<tr>
<td>4.</td>
<td>Orange</td>
<td>720</td>
<td>80</td>
<td>20.07.10</td>
<td>102.0</td>
<td>10.50</td>
<td>-</td>
</tr>
<tr>
<td>5.</td>
<td>Pineapple</td>
<td>200</td>
<td>596</td>
<td>01.09.10</td>
<td>-</td>
<td>-</td>
<td>402</td>
</tr>
<tr>
<td>6.</td>
<td>Papaya</td>
<td>240</td>
<td>81</td>
<td>08.07.10</td>
<td>254.0</td>
<td>24.12</td>
<td>55</td>
</tr>
</tbody>
</table>

The inter space of this orchard block was made productive by growing sweet potato, cowpea, brinjal as ground cover crop while pineapple and papaya were the second storied crop. Total area under fruit crop (1540 sq m) was utilized for growing of intercrops. The production potential of this intercropping system could fetch Rs. 16,080.00 (Table 3).

Table 3: Income through intercropping in newly established orchard in horticulture block

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Cropping system</th>
<th>Area (m²)</th>
<th>Production (kg)</th>
<th>Gross Income (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Sweet potato</td>
<td>340</td>
<td>67</td>
<td>670.00</td>
</tr>
<tr>
<td>2.</td>
<td>Cowpea-Brinjal cropping system</td>
<td>390</td>
<td>70</td>
<td>3,850.00</td>
</tr>
<tr>
<td>a).</td>
<td>Cowpea</td>
<td>390</td>
<td>70</td>
<td>3,850.00</td>
</tr>
<tr>
<td>b).</td>
<td>Brinjal</td>
<td>370</td>
<td>264</td>
<td>2,640.00</td>
</tr>
<tr>
<td>3.</td>
<td>Papaya-Pineapple inter cropping with fruit plant</td>
<td>240</td>
<td>55</td>
<td>1100.00</td>
</tr>
<tr>
<td>a).</td>
<td>Papaya</td>
<td>240</td>
<td>55</td>
<td>1100.00</td>
</tr>
<tr>
<td>b).</td>
<td>Pineapple</td>
<td>200</td>
<td>402</td>
<td>4,020.00</td>
</tr>
<tr>
<td>4.</td>
<td>Guava</td>
<td>675</td>
<td>380</td>
<td>3,800.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1540</td>
<td>1238</td>
<td>16,080.00</td>
</tr>
</tbody>
</table>

3. Productivity and economic dynamics of livestock component in IFS

In livestock component of Integrated Farming System, 575 broiler chicks were reared in 4 rotations each for a cycle of 40-45 days. The 10-15 days were the gap period between two cycles for cleaning and disinfections of the shed. In broiler poultry production 16.7% mortality was observed which resulted in 479 number marketable broiler productions. The final weight of broiler was 1070.7 kg with an average weight of 2.30 kg/bird. The total cost of broiler production was Rs. 95,800.00 with gross returns of Rs.1, 02,680.00 and hence, net profit of Rs. 6,880.00 was realized from broiler production. Besides, 130 layer birds of Vanaraja were maintained on the farm for the egg production and meat. The poultry breed Vanaraja which is mostly liked by the local people was kept in this herd. The total cost of layer production was Rs.63, 100.00 while the gross income was Rs. 67,440.00. The net return from layer poultry was Rs. 4,340.00. The less income from layer poultry was due to high cost of chicks as well as feed concentrate.
Piggery comprised the third livestock component of farming system. Generally, the farmers reared 2-3 no. pigs per family. Hence, keeping in view the farmer’s requirement and desire, 03 numbers of pigs were reared in the system. Table 8 displayed the pigs’ species of Hampshire X Khasi Local where they were reared for 304 days and the initial weight of piglet was 18 kg/piglet. While at maturity the final weight was observed to be 153.3 kg/pig totaling 460.0 kg live weight from 3 no. of pigs. The total cost of production was worked out to be Rs. 44,330.00, while the gross return was Rs. 46,000.00. The net return of Rs 1670.00 was realized from 3 no. pigs. Hence, the average net return Rs. 556.66/pig was recorded. The net return was less because of high cost of piglets and feed concentrate which reduced the net return from piggery unit and due to this high cost the piggery unit is not a profitable enterprise.

4. **Production economics of Fishery component in IFS**

500 sq m area was assigned under fish pond lined with polythene sheet and tested for water storage. Total 500 fingerlings were released in the fish pond for experimentation. The harvested water was utilized for giving one pre-sowing irrigation to french-bean and one supplementary irrigation to standing crop of toria. Hence, with the help of harvested water, the cropping intensity of farm area of 2300 sq m was brought to 300%. Besides, the water was also utilized to increase cropping intensity up to 300% of vegetable based cropping system in 700 sq m area. From this harvested water, fish weight of 80.10 kg was recorded and sold at farm gate price. The harvested fish gave a gross return of Rs.9,614.00 with the cost of cultivation of Rs. 4,500.00 and hence the net income was Rs. 5,257.00/annum from fishery unit.

**Economics and energetics of IFS model**

As a whole, the Integrated Farming System recorded gross return of Rs. 4,62,192/- with net returns of Rs 1,66,424/-/ha/annum was estimated from one hectare area. Model is able to generate Rs 453/ per day besides generating 691 man-days employment. With regards to energy generation and residue recycling, system generated 175.5 x10³ MJ energy and recycled 8.54 t biomass/ha.

**Table 4**: Production and net retunes of different components in IFS model

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Module</th>
<th>Net Area (m²)</th>
<th>Production (REY t/year)</th>
<th>Net returns (Rs/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Crop production (cereals, pulses, oilseeds, fodder &amp; vegetables)</td>
<td>7000</td>
<td>13.96</td>
<td>1,14,455</td>
</tr>
<tr>
<td>2</td>
<td>Fruit Crops</td>
<td>2000</td>
<td>2.00</td>
<td>6,480</td>
</tr>
</tbody>
</table>
## Training Manual on "Integrated Farming System for Sustainable Hill Agriculture: An Option for Climate Smart Agriculture and Natural Resource Management"

<table>
<thead>
<tr>
<th></th>
<th>Activity/Unit</th>
<th>No.</th>
<th>Area/Output</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Piggery</td>
<td>100</td>
<td>3.06</td>
<td>1,710</td>
</tr>
<tr>
<td>4</td>
<td>Poultry</td>
<td>200</td>
<td>7.14</td>
<td>6,880</td>
</tr>
<tr>
<td>5</td>
<td>Layer</td>
<td>100</td>
<td>4.50</td>
<td>4,340</td>
</tr>
<tr>
<td>6</td>
<td>Fishery (Fish+ Vegetables on Pond Dyke through intensification)</td>
<td>500 sqm Water Bodies + 644 sqm on Pond dyke</td>
<td>0.96(Fish)+ 0.62 (Vegetables)</td>
<td>13,578</td>
</tr>
<tr>
<td>7</td>
<td>Vermicompost Unit-1Nos</td>
<td>53.2</td>
<td>13.25</td>
<td>19,200</td>
</tr>
<tr>
<td>8</td>
<td>Others (Threshing Floor &amp; Misc.)</td>
<td>46.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total (Including household area)</strong></td>
<td>10,000</td>
<td><strong>32.24</strong></td>
<td><strong>1,66,424</strong></td>
<td></td>
</tr>
</tbody>
</table>

### Entrepreneurship Development and Organic Based Integrated Farming System

Entrepreneurship is a process that encourages ingenuity, planned risk-taking, and business planning to take advantage of opportunities. The process enables the business to show profit by identifying market opportunities and creating unique combinations of resources to follow these opportunities. Rural entrepreneurship frequently includes agriculture-related enterprises, including opportunities for family farms. Organic farming based IFS means holistic production systems which refer soil friendly methods for cultivation and food processing. Eco-friendly techniques are employed to increase the production. It is based on the integral relationship and we need to understand the relationship between different entities of a farm. IOFS is a method which recognizes the ecological interconnections between different compartments of farming. The diversity at farm level creates an ecosystem that has biological checks and balances. Organic farming based ISF by incorporating various components provides dual-career opportunities to the farm families. This can mean employment off the farm or expanding enterprises on the farm to intensify farm business management. By adopting OIFS small and medium-sized farms can become (a) producers and marketers of niche products that are unattractive to large farm organizations and (b) use technologies that allow them to be more productive in their efforts. Their challenge is to change a farm operation from a price taker to a price maker. Family farms can become more entrepreneurial and employ niche strategies to improve in on niche target markets, but only after thorough market analysis done prior to any expanded investment in alternative crop production or other ventures.

**Integrated farming system increased employment manifold by following ways**

1. Processing of the agricultural products
2. Proper packaging
3. Seasonal fruits and vegetables having greater production
4. Processing of seeds for organic crops
5. Use of sprinkler method of irrigation in greater use
6. Use of other forms of energies which save the fuel like solar energy
7. Production of vermicompost at commercial scale
8. Various components like bee keeping, dairy, poultry, piggery are the major driven for developing agripreneurship

Conclusions

Organic farming based Integrated Farming is basically whole farm management tactic that syndicates the ecological care of a diverse and healthy environment with the economic demands of agriculture to safeguard a continuing supply of healthy, affordable food. In totality, organic farming based Integrated Farming is a practical way advancing for agriculture that will benefit all society by offering various kinds of employment and income consistently. Hence, organic farming based Integrated Farming makes a vivacious contribution to sustainable development by totalling attention of economic, ecological and social aims to the essential business of agricultural food production.
Biomass management and carbon sequestration: a mitigation strategy to climate change

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Sustainable and resilient cropping systems are required to arrest declining soil fertility and offset the future negative effects of climate change. Conservation agriculture (CA) has been proposed as a potential system for improving soil quality and providing stable yields through minimum soil disturbance, surface crop residue retention (mulching) and crop rotations or associations. Agriculture in the next decade will have to produce more food from less area of land through more efficient use of natural resources with minimal impact on the environment in order to meet the growing population demands. Of late, it has been established that disturbing the soil too much through tillage operations is not actually required to obtain good crop yields and prone soil erosion. It also a major portion of energy (25–30%) in agriculture is utilized for either field preparation or crop establishment, where conventional tillage is mostly followed. The characteristics of hill agriculture in Manipur are Cutting and clearing of forest areas, burning of the dried biomass by fire, rotation of field rather than crops, mixed cropping system and Degraded & infertile soils as a result of continuous monocropping and insufficient organic matter recycling coupled with occurrence of rainfall variability marked by frequent dry spells account for low crop yields. In era of climate change, various questions arising especially in hill agriculture like what’s effect of residue burning and jhuming on soil quality and rhizospheric environment? Is it required to change in management practice among marginal and sub marginal farmers under hill climate? What technologies will be economically viable for small and marginal farmers? How we can conserve the natural resources in hill agriculture? The proposed project will aim not only the standardization of bio manuring and their management under various cropland systems, but also cover the rhizospheric changes in soil quality, terrestrial carbon sequestration and soil-water-nutrient conservation. It is important to determine SOC sequestration rates for various agricultural land treatments and to establish a protocol to validate the amount and rate of SOC sequestration level and linked to a net depletion of atmospheric CO2. The technology can be refined in future on other cropping pattern in climate change (Ansari et al., 2017). Climate change poses a threat to food security in tribal populated area due to shifting cultivation, where economies are highly dependent on agriculture (IPCC, 2007). Thornton et al., (2011) estimated a 24–71% decrease in crop yields by 2090, and in places a shift from crop production to livestock husbandry, although these figures (Fig 1) imply a high degree of uncertainty. Simultaneously, high population growth and soil degradation exert pressures to increase agricultural productivity. Carbon (C)
Sequestration in agricultural soils has the greatest potential to mitigate climate change in North East Indian agriculture, and to increase agricultural productivity. In farming systems, food security and C sequestration can be enhanced by allocating a high share of harvested C to food and agricultural soil. Such development can be contributed to by reducing C losses before harvested C ends up in food or soil. In agriculture, carbon dioxide (CO₂) is assimilated during photosynthesis in crops and rangelands. Part of this C is released back into the atmosphere during plant and soil respiration or fire, part of it being stored in soil organic matter (SOM) and in harvested biomass and animal products, and part being liable to erosion and leaching as dissolved organic and inorganic carbon and methane. Biomass C is harvested as crops and through grazing of livestock and collecting fuel wood. Harvested C can also be imported into the farm as fodder, food, fuel, construction material and organic soil amendments. The quantity of harvested C lays the ground for availability of food and soil amendment, but there are also other competitive uses for these resources.

Introduction of sustainable integrated farming system (SIFS) in North East India helps to safeguarding agricultural systems for better livelihood and food security of tribal farmers with biodiversity value. Despite its importance, SIFS has been declining due to agricultural abandonment and afforestation in marginal farming areas, coupled with non-strategic and systematic intensification in the most productive areas. The farming system framework may provide a relatively simple and practical approach to evaluate agricultural changes in SIFS, because it concentrates on groups of farms with similar typology, thereby avoiding the need to detail the multiple idiosyncrasies of a large number of individual farms. Farms included in the same farming system type have similar resource bases, enterprise patterns, livelihoods and household restrictions, and so they are expected to show similar responses to policy, market and biophysical drivers (Dixon et al., 2001). Furthermore, information on potential biodiversity impacts can be gained by analyzing changes in farming systems, because they are associated with specific agricultural practices and land-use patterns to which biodiversity components respond (Bamière et al., 2011).

**Biomass management**

Indian agriculture produces about 500-550 million tonnes (Mt) of crop residues annually. These crop residues are used as animal feed, soil mulch, manure, thatching for rural homes and fuel for domestic and industrial purposes and thus are of tremendous value to farmers. However, a large portion of these crop residues, about 90-140 Mt annually, is burnt on-farm primarily to clear the fields to facilitate planting of succeeding crops. The problem of on-farm burning of crop residues has intensified in recent years due to use of combines for harvesting and high cost of labours in removing the crop residues by conventional methods. The residues of rice, wheat, cotton, maize, millet, sugarcane, jute, rapeseed-mustard and groundnut crops are typically burnt on-farm across the country. This problem is severe in irrigated agriculture and North East India, particularly in
northwest India where the rice-wheat system is mechanized and NE India in rice based system. Burning of crop residues leads to plethora of problems such as release of soot particles and smoke causing human health problems; emission of greenhouse gases such as carbon dioxide, methane and nitrous oxide adding to global warming; loss of plant nutrients such as N, P, K and S; adverse impacts on soil properties and wastage of valuable crop residues. It is a paradox that burning of crop residues and scarcity of fodder co-exists in this country, when fodder prices have surged significantly in recent years. Much of the paradox owes it to non-availability and easy access of the quality crop planters which can seed into loose and anchored residues. There are several options such as animal feed, composting, energy generation, biofuel production and recycling in soil to manage the residues in a productive and profitable manner. Use of crop residues as soil organic amendment in the system of agriculture is a viable and valuable option.

Production of crop residues in Indian agriculture

According to Ministry of New and Renewable Energy (MNRE, 2009), Govt. of India approximately 500.0 Mt of crop residues are generated every year. Depending on the crops grown, cropping intensity and productivity in different regions of India, there is a large variability in generation and end use of these crop residues. The crop residues generation is the highest in Uttar Pradesh (60.0 Mt) followed by Punjab (51.0 Mt) and Maharashtra (46 Mt) (Figure 2). The cereal crops (rice, wheat, maize, millets) contribute 70% (rice 34% and wheat 22%) of crop residues. Among fiber crops, cotton generates maximum (53.0 Mt) with 11% of crop residues. Coconut ranks second among fiber crops with 12.0 Mt of residues generation. Sugarcane generates 12.0 Mt i.e., 2% of crop residues (comprising of tops and leaves) in India. A large amount of residues are, in addition, generated from fruit, vegetable and fodder production. The unutilized crop residues i.e., total residues generated minus residues typically used for various purposes are burnt on-farm. Estimated total crop residues unutilized in India is 84-141 Mt yr-1 where cereals and fiber crops contribute 58% and 23%, respectively. Sugarcane, pulses, oilseeds and other crops contribute to the remaining 19%. Out of 82 Mt surplus crop residues from the cereal crops, 44 Mt is from rice crop followed by 24.5 Mt from wheat crop, which is mostly burnt on-farm. In case of fiber crops (33 Mt of unutilized residues) approximately 80% is cotton residues and are subjected to on-farm burning. There are large uncertainties in the data on generation of crop residues, their uses, the remaining surplus and on-farm burning. Besides the estimates of MNRE (2009), Pathak (2004) estimated that annually about 525 Mt crop residues are available in India, out of which about 125 Mt are surplus. Pathak et al., (2010) estimated that about 90 Mt of crop residues are burnt on-farm and this figure is close to 85 Mt when the coefficients developed by the Inter-Governmental Panel on Climate Change (IPCC) are used.

Utilization of crop residues under conservation agriculture

Conservation agriculture (CA) aims at achieving sustainable agriculture and improved livelihoods of farmers through the application of the three basic principles: minimal soil
disturbance, permanent soil cover and crop rotations (FAO, 2007). No-till agriculture is considered as a revolutionary step in the direction of preventing land degradation and rehabilitation of the resilient but fragile lands (Kasam, 2011). Frameworks such as ‘conservation agriculture’ (FAO, 2007), ‘ecological intensification’ (Cassman, 1999) and ‘evergreen revolution’ (Swaminathan, 2000) share a view of cropping systems as agro-ecosystems designed to make maximum use of fixed resources (land, light, temperature, etc.) and optimum use of agri-inputs for attaining sustainable production levels. These systems tap traditional knowledge of the farmers and add new information relevant to the specific ecologies for the intensification process (Matson et al., 1997). The conservation agriculture systems (i.e., zero-till systems) are ‘flexible’ in operation allowing farmers to benefit from them under diverse situations. Conservation agriculture-based resource conserving technologies (RCTs) are ‘open’ approaches, easier to mainstream and be adapted even in conventional agriculture systems.

The conservation agriculture is an innovative process of developing appropriate implements, early maturing crop cultivars, etc. for an iterative guidance and fine-tuning of crop production technologies. Many variants of reduced till and cropping systems have been adopted by farmers in tropical/subtropical and temperate regions of the world for improved yields. The conservation agriculture has steadily increased worldwide to cover about 7% of the world arable land area, i.e., about 105 million ha. However, only few countries i.e., USA, Brazil, Argentina, Canada and Australia share about 90% of this area (Derpsch and Friedrich, 2010). The Food and Agricultural Organization (FAO) of the United Nations has adopted the conservation agriculture as a lead model for sustainable production intensification (FAO, 2007). Permanent crop cover with recycling of crop residues is a pre-requisite and an integral part of conservation agriculture. However, sowing of a crop in presence of residues of preceding crop was a problem. But new variants of zero-till seed-cum-fertilizer drill/planters such as Happy Seeder, Turbo Seeder, rotary-disc drill and easy seeder have since been developed to facilitate direct drilling of seeds in the presence of surface retained residues (both loose and anchored residues up to 10 tonnes ha-1). The crop residues retained on surface help conserving moisture and nutrients and controlling weeds in addition to moderating soil temperature. Several studies conducted across the production systems under varied ecologies of South Asia have revealed potential benefits of conservation agriculture-based crop management technologies on resource conservation, use-efficiency of external inputs, yield enhancement, soil health improvement, and adaptation to changing climate (Gupta and Seth, 2007). Results of farmers’ participatory field trials across Indo-Gangetic Plains have revealed that zero tillage helps in timely sowing of wheat crop.

The terminal heat effects are also less in zero tillage compared to conventional till even under late planting. Zero-till drilling in crop residues keeps canopy temperatures lower by 1-1.5ºC during grain filling stage and sustains soil moisture availability to the plants (Jat et al., 2009). Surface retention of crop residues increases N uptake and yield and improves...
the soil physical properties in rice-wheat systems (Mandal et al., 2004). Though residues incorporation leads to immobilization of inorganic N but addition of 15-20 kg N with straw incorporation increases the yield of rice and wheat. In the areas, for example, eastern India, where crop residues have competing uses such as animal feed, roof thatching and domestic fuel, at least some parts of the stubble should be left in the fields to contribute to soil organic C. The value of crop residues retained over soil surface in crop production vis-à-vis livestock production has been demonstrated locally and globally through several reports in recent years (Joshi et al., 2010). Due to limited production of biomass, competing uses of crop residues and shortage of firewood, farmers often find it hard to use crop residues to cover soil surface in dryland eco-systems. However, Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad showed that in dryland eco-systems, where only a single crop is grown in a year, it is possible to grow a second crop with residual soil moisture in the profile under conservation agriculture with soil cover with crop residues. It is, however better to use the chopped biomass of semi-hard woody perennial plants instead of crop residues to cover the soil surface. Sustainability is a concern in today's agriculture and conservation agriculture constitutes a sound approach for moving in this direction (Hobbs et al., 2008). There are three major benefits from conservation agriculture: (1) increase in organic matter, (2) increase in water availability and (3) improvement of soil structure (FAO, 2007). The task of the scientists is to convince farmers that retaining crop residues has both short and long term advantages which outweigh the benefits which they might otherwise be getting. It is always a challenge for the farmers to place seed at appropriate soil depths in the moist soil zone and band place the fertilizer nutrients to avoid any damage to seed. In presence of the loose straws retained over the soil surface, planter begins to rake the crop residues making it extremely difficult to drill the seed properly. Presence of crop residues on the soil surface also makes it difficult to top dress the fertilizers in the root zone. Although a lot of improvement has been made in the zero-till seed-cum-fertilizer drill machinery, there is still a lot of scope for further improvement to give farmers a hassle-free technology. Although crop residues mulch helps in reducing weed population, it requires special efforts to mechanically control weeds early in the season in presence of the crop residues. Nutrient management may become complex because of higher crop residues levels and reduced options with regard to method of nutrient applications. No-till, in particular, can complicate manure application and may also contribute to nutrient stratification within soil profile from repeated surface applications without any mechanical incorporation.

With higher crop residues levels, however, evaporation is reduced and more moisture is maintained near the soil surface favouring the growth of feeder roots where the nutrients are concentrated. In some instances, increased application of specific nutrients and specialized equipment for proper fertilizer placement may be necessary, thereby contributing to higher costs. The limiting factor in the adoption of crop residues incorporation by farmers includes additional management skill requirement,
apprehension of lower crop yields and/or economic returns, negative perceptions, and institutional constraints. Farmers often prefer clean tilled fields to obtain a smooth surface for planting.

**Crop residue in relation to soil and environmental quality**

Principal benefits of retaining crop residue include soil erosion control, maintenance of soil structure, moderation of soil moisture and temperature regimes, energy source for soil biota and maintenance of soil organic matter (SOM) content. Several studies have been conducted to assess the amount of crop residue required to control soil erosion. The residue requirement for soil erosion control depends upon soil erodibility (Lindstrom and Holt, 1983; Lindstrom, 1986), rainfall erosivity, terrain characteristics, land use, farming system, tillage methods and other soil/crop management practices. Some studies have reported that 20–40% of the corn residue produced in the US Corn Belt can be removed for biofuel (ethanol) production if soil erosion control is the only objective of residue retention (Nelson, 2002; McAloon *et al*., 2000; Kim and Dale, 2004). However, enhancing and maintaining soil quality are among the principal reasons for residue retention on the soil surface. Further, providing adequate ground cover for achieving a satisfactory level of erosion control is not sufficient to enhance or maintain a desirable level of SOM. Removal of crop residue even that in excess of effective erosion control below the tolerable limit can lead to decline in SOM content (Wilhelm *et al*., 2004). In addition to the C, crop residue is also a source of macronutrients (N, P, K) and micronutrients (S, Cu, B, Zn, Mo) needed for crop growth and humification of residue (Mubarak *et al*., 2002).

Decline in SOM content is exacerbated by reduction in soil aggregation and the overall decline in soil structure (Carter, 2002). Crop residue is also an essential source of energy for all microbial processes in soil (Franzluebbers, 2002), which are essential to both formation and stabilization of aggregates and recycling of nutrients. Crop residue and SOM are principal components of the global C cycle and directly impact upon atmospheric concentration of CO\(_2\). Conversion of natural to agricultural ecosystems, along with the attendant biomass burning and follow up soil cultivation leading to erosion, causes depletion of the SOM pool. The resultant increase in mineralization leads to emission of CO\(_2\) into the atmosphere. Thus, a large amount of the relic C in SOM has been released into the atmosphere since the dawn of settled agriculture some 10,000 years ago (Ruddiman, 2003). With restoration of degraded soils and ecosystems and adoption of RMPs, a large portion of the depleted SOM pool can be recovered in agricultural and forest soils. The sink capacity of the world soils has a potential to sequester 0.6–1.2 Pg C/year (Lal, 2004). In addition to mitigating atmospheric enrichment of CO\(_2\) and reversing soil degradation trends, there are several important ancillary benefits of C sequestration in SOM including reduction in erosion and sedimentation, decline in non-point source pollution, increase in soil biodiversity, improvement in biomass productivity and sustainability of agricultural systems. Within limits, which vary
with soil type and crop species, there exists a direct relationship between SOM pool and agronomic productivity (Lal, 2004). Such a positive relationship exists because of the beneficial impact of SOM on soil structure and aggregate stability, soil tilth (Carter, 2002), soil moisture retention (Wilhelm et al., 1986) and microbial processes (Franzluebbers, 2002). Improvement in plant available water capacity with increase in SOM content is an important factor affecting crop yields and sustainability (Lal, 2004). All other factors remaining the same, the SOM content is directly related to the amount of crop residue returned to the soil (Carter, 2002). Therefore, removal of the crop residue may lead to decline in soil quality and reduction in agronomic productivity. Several studies have documented the magnitude of yield decline with continuous removal of crop residue.

**Significance of carbon sequestration**

![Fig 1. Impact of soil organic carbon on atmosphere, pedosphere, hydrosphere and biosphere](image)

**Utilization and integration of crop residues/by products under ifs**

Integrated farming system works as a set of systems. From crop production, farmers were getting straw and stover which was used for compost preparation and compost was used for the crop production, vegetable production and fruits production as well as applied in fish ponds. In the same way, poultry and piggery manure from poultry and piggery farming was used for the aforesaid components (Fig 2). When farmers got excess or waste materials from horticulture, they used it as feed materials for piggery. In integrated farming system, rain water harvesting is playing pivotal role in sustainable
production. This water used as a lifesaving for different components of integrated farming system.

![Diagram of integrated farming system](image)

**Fig 2. Recycling and linkage of by products, waste materials to one enterprise to another enterprise (Ansari et al., 2014)**

**Carbon Sequestration**

Carbon sequestration describes long-term storage of carbon dioxide or other forms of carbon to either mitigate or defer global warming and avoid dangerous climate change. It has been proposed as a way to slow the atmospheric and marine accumulation of greenhouse gases, which are released by burning fossil fuels. (https://en.wikipedia.org/wiki). One source of the conflicting findings relates to the general nature of the definition of SOC sequestration. Soil organic carbon (SOC) sequestration was defined by Olson (2010) as “Process of transferring CO$_2$ from the atmosphere into the soil through plants, plant residues and other organic solids, which are stored or retained as part of the soil organic matter (humus). The retention time of sequestered carbon in the soil (terrestrial pool) can range from short-term (not immediately released back to atmosphere) to long-term (millennia) storage. The sequestrated SOC process should increase the net SOC storage during and at the end of a study to above the previous pre-treatment baseline levels and result in a net reduction in the CO$_2$ levels in atmosphere.” The phrase “of a land unit” needs to be added to the definition proposed by Olson (2010) to add clarity and to prevent the loading or adding SOC to the land unit soil naturally or artificially from external sources. Carbon not directly from atmosphere and from outside the land unit should not be counted as sequestered SOC. These external inputs could include organic fertilizers, manure, plant residues, or
topsoil or natural input processes such as erosion of a sloping soil and sediment rich C deposition on a soil located on a lower landscape position or in a waterway. The land unit could be a plot, plot area, parcel, tract, field, farm, landscape position, landscape, wetland, forest or prairie with defined and identified boundaries. This paper only discusses SOC sequestration as defined in the proposed definition and not soil inorganic carbon (SIC), OC or C sequestration. Atmospheric carbon is cycled to the plant by photosynthesis, the plant cycles the organic C to the soil as residue and it becomes humus or soil organic matter. It is impossible for most researchers, with the possible exception of modelers, to quantify changes in both the terrestrial and atmospheric pools. Therefore the soil sequestration definition needs meaningful boundaries to be used by researchers who want to measure actual changes in a specific part of a terrestrial (soil) pool. The proposed definition of soil sequestration is the “process of transferring CO$_2$ from the atmosphere into the soil of a land unit through unit plants, plant residues and other organic solids, which are stored or retained in the unit as part of the soil organic matter (humus).”
The various C index used for the determination of soil organic carbon in soil as follows

SOC storage (Mg C ha\(^{-1}\)) = [%C X BD (Mg m\(^{-3}\)) X d (m) X 10\(^4\) m\(^2\) ha\(^{-1}\)]/100  

The amount of C retained in the entire 0-30 cm depth was estimated as SOC retaining

(Mg C ha\(^{-1}\)) = (SOC\(_{\text{current}}\) - SOC\(_{\text{initial}}\))  

Carbon retention efficiency (CRE) was calculated by the following relationship following Bhattacharyya et al. (2009b)

\[
\text{CRE} \% = \left(\frac{\text{SOC}_{\text{final}} - \text{SOC}_{\text{initial}}}{\text{ECI}}\right) \times 100
\]

SOC final and SOC initial represent SOC (Mg ha\(^{-1}\)) in the final and initial soils, respectively, and ECI is cumulative estimated C input (Mg ha\(^{-1}\)) to soil between the initial and final year of experimentation. The carbon based sustainability index (CSI) was calculated using following formula (Lal, 2004):

\[
\text{Cs} = \left(\frac{\text{Co} - \text{Ci}}{\text{Ci}}\right) 
\]

Where, Cs – Sustainability Index, Co – Carbon Output, Ci – Carbon Input

Carbon Management Index (CMI) = Carbon Pool Index (CPI) X Lability index (LI) X 100  

CPI = [Sample total C (mg g\(^{-1}\))/Reference total C (mg g\(^{-1}\)], Blair et al., 1998= 47.2 mg g\(^{-1}\)  

LI= (Lability of C in sample soil)/ (Lability of C in reference soil)  

Lability of C (L) = Carbon fraction oxidized by KMnO\(_4\)/Carbon remaining non oxidized by KMnO\(_4\)
Role of soil carbon sequestration in climate mitigation over the next century

Smith (2004) recently examined the potential for soil carbon sequestration over the next century by examining emission trajectories predicted for the IPCC standard reference emission scenarios (SRES). The future trajectory of carbon emissions over the next century depends upon many factors. The IPCC SRES scenarios provide estimates of possible emissions under a range of different possible futures (IPCC, 2000a). These possible futures depend upon the degree to which society/policy becomes globalised and upon whether environmental or economic concerns take precedence over the next century.

![Diagram of SRES scenarios](image)

*Fig. 3*

Fig. 3 summarizes some of the main characteristics of the various IPCC-SRES scenarios. Among the A1 family of scenarios (global—free market), a number of possible emissions trajectories exist depending upon whether the energy sector remains fossil fuel intensive (A1FI), whether the rapid introduction of new energy technologies allows a move away from carbon intensive energy sources (A1T) or a balanced mix of fossil fuel/alternative energy sources (A1B). In all of the SRES scenarios, over the next century, the global population will grow, the population will become wealthier and per capita, energy demand will increase (IPCC, 2000b). The extent to which these changes will occur differs between different SRES scenarios with some showing larger increases than others, but in all scenarios, these trends are observed. For each of the SRES scenarios carbon emission trajectories have been determined (IPCC, 2000b). Yearly carbon emissions (Pg C per year) by 2100 under the SRES scenarios are A1FI~30, A1B~17, A1T~10, A2~28, B1~10, B2~15. Emissions trajectories can also be calculated for a range of atmospheric CO2 stabilization targets (e.g. 450, 550, 650, 750 ppm). For each stabilization target, the allowed carbon emission trajectories, which cannot be exceeded if the target is to be reached, can be calculated. The difference between the allowed emission trajectory for stabilization at a given target concentration and the emissions associated with the estimated global energy demand is the carbon emission gap. For each of the SRES scenarios, the carbon

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Note: The text partially overlaps with the image, indicating that the diagram is not the entire page. The diagram is labeled as 'Fig. 3' and shows different scenarios labeled A1 – “World Markets”, A2 – “Provincial Enterprise”, B1 – “Global Sustainability”, and B2 – “Local Stewardship”. The scenarios are categorized as Economically oriented and Environmentally oriented.
emission gaps by 2100 (for a stabilization target for atmospheric CO2 concentration of 550 ppm) for each scenario by 2100 (PgC per year) are A1FI = 25, A1B = 10, A1T = 1, A2 25, B1 = 1, B2 = 10 (IPCC, 2001). The current yearly emission of CO2-carbon to the atmosphere is 6.3±1.3 PgC per year (IPCC, 2001). Carbon emission gaps by 2100 could be as high as 25 PgC per year meaning that the carbon emission problem could be up to four times greater than at present. The maximum yearly global soil carbon sequestration potential is 0.9 ± 0.3PgC per year (Lal, 2004) meaning that even if these rates could be maintained until 2100, soil carbon sequestration could contribute a maximum of 2–5% towards reducing the carbon emission gap under the highest emission scenarios. When we also consider the limited duration of carbon sequestration options in removing carbon from the atmosphere, it is seen that carbon sequestration can play only a minor role in closing the emission gap in 2100. It is clear from these figures that if we wish to stabilize atmospheric CO2 concentrations by 2100, the increased global population and its increased energy demand can only be supported if there is a large-scale switch to non-carbon emitting energy technologies. Given that soil carbon sequestration will play only a minor role in closing the carbon emission gap by 2100, is there any role for carbon sequestration in climate mitigation in the future? The answer is yes. If atmospheric CO2 levels are to be stabilized at reasonable concentrations by 2100 (e.g. 450–650 ppm), drastic reductions in emissions are required over the next 20–30 years (IPCC, 2000b). During this critical period, all measures to reduce net carbon emissions to the atmosphere will play an important role—there will be no single solution. Given that carbon sequestration is likely to be most effective in its first 20 years of implementation, it should form a central role in any portfolio of measures to reduce atmospheric CO2 concentrations over the next 20–30 years whilst new energy technologies are developed and implemented.

**Energy Budgeting**

Modernization of agriculture, in general, tied with increasing inputs of energy in crop production. The energy use efficiency is declining consistently (Mandal *et al*., 2002). Energy input–output relationships in cropping systems vary with the crops grown in a sequence, type of soils, type of tillage operations, nature and chemical fertilizers, plant protection measures, harvesting and threshing operations, yield levels and biomass production (Baishya and Sharma, 1990; Singh *et al*., 1997). The energy inputs include both operational (direct) and non-operational (indirect) energy. Operational energy comprised manual work, fuel, machinery, etc., whereas, non-operational energy consisted of seed, manure and chemical fertilizer (NPK) and agro-chemicals. Sowing was carried out with a tractor-drawn seed drill. On the other hand, energy is an essential input to production, transport, and communication process and is thus a driver of economic as well as social development.

Nowadays, energy usage in agricultural activities has been intensified in response to continued growth of human populations and tendency for an overall improved standard
of living within a limited supply of arable land (Rafiee et al., 2010). Rational and effective use of energy resources in agriculture is one of the principal requirements for sustainable development; it will minimize environmental problems, prevent destruction of natural resources and promote sustainable agriculture as an economical production system (Rafiee et al., 2010). Calculating energy inputs of agricultural production is more difficult than in the industry sector due to the high number of factors affecting agricultural production (Rafiee et al., 2010). The analysis of energy usage is important to ascertain more efficient and environment friendly production systems (Schroll, 1994). There are various energy equivalent of agriculture inputs ae given in Table 1 for calculation of energy budgeting. Table 1 Energy equivalent for different inputs and outputs

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Units</th>
<th>Equivalent energy (MJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Inputs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Human labour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Adult man</td>
<td>Man-hour</td>
<td>1.96</td>
</tr>
<tr>
<td>b. woman</td>
<td>Woman-hour</td>
<td>1.57</td>
</tr>
<tr>
<td>2. Diesel</td>
<td>L</td>
<td>56.31</td>
</tr>
<tr>
<td>3. Patrol</td>
<td>L</td>
<td>48.23</td>
</tr>
<tr>
<td>4. Electricity</td>
<td>Kw h</td>
<td>11.93</td>
</tr>
<tr>
<td>5. Machinery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Electric motor</td>
<td>Kg</td>
<td>64.8</td>
</tr>
<tr>
<td>b. Farm machinery including self-propelled machine</td>
<td>Kg</td>
<td>62.7</td>
</tr>
<tr>
<td>6. Chemical fertilizers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Nitrogen</td>
<td>Kg</td>
<td>60.6</td>
</tr>
<tr>
<td>b. Phosphorus</td>
<td>Kg</td>
<td>11.1</td>
</tr>
<tr>
<td>c. Potash</td>
<td>Kg</td>
<td>6.7</td>
</tr>
<tr>
<td>d. biofertilizers</td>
<td>Kg</td>
<td>0.3</td>
</tr>
<tr>
<td>7. Chemicals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Superior chemicals</td>
<td>Kg</td>
<td>120</td>
</tr>
<tr>
<td>8. Depreciation for per diesel fuel</td>
<td>L</td>
<td>92.4</td>
</tr>
<tr>
<td><strong>B.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Main product</td>
<td>Kg</td>
<td>-</td>
</tr>
<tr>
<td>b. By product</td>
<td>Kg</td>
<td>-</td>
</tr>
</tbody>
</table>

**Energy calculation equations**

Energy input=Energy spent in cultivation of crops/rearing of livestock 

Energy output= Energy gain as output from crop/livestock

Energy use efficiency (EUE) = energy output (MJ⁻¹) ÷ energy input (MJ⁻¹)

Energy production (EP)= Grain yield (kg ha⁻¹)/ Input energy (Mj ha⁻¹)

Energy specific (Es)= Input energy (Mj ha⁻¹)/ Grain yield (kg ha⁻¹)

Net Energy gain= Output energy (MJ ha⁻¹)- Inputenergy (Mj ha⁻¹)
Conclusion

Benefits of Biomass management and carbon sequestration is enhancement of SOC pool, climate change mitigation, advancing food security and improving the environment depend on retention of crop residues as mulch. Carbon sequestration is integral tool for maintain bio chemical and biophysical variability of soil at optimum required level. For promotion of carbon sequestration at farmers field, government should start with public private partnership in the form of Carbon farming, treading C credits as another income stream, is an important strategy to provide incentives for promoting adoption conservation agriculture. For C trading to be effective, it is important to establish the fair/transparent value of C based on the societal values and ecosystem services.

Crop residues are an important resource, with numerous competing uses. However, the most appropriate use of crop residue is to enhance, maintain and sustain soil quality by increasing the soil organic carbon pool, enhancing activity and species diversity of soil fauna, minimizing soil erosion and non-point source pollution, mitigating climate change by sequestering C in the pedosphere and advancing global food security through enhancement of soil quality. There exists a direct relation between the amount of residue retained and soil organic matter content on the one hand, and between soil organic matter content and crop yields on the other. Production of biomass for biofuel, an important strategy for off-setting fossil fuel emissions, must be undertaken on specifically dedicated land to grow species with a potential to produce high biomass. The economics and environmental consequences of competing uses of crop residue must be assessed objectively with a holistic approach and long-term perspective. In another hand, rising energy prices and changing energy and environmental policies over the last decade have transformed the relationship between the agriculture and energy sectors. While the agricultural sector has traditionally used energy both directly in the form of fuel and electricity and indirectly through use of energy-intensive inputs, such as fertilizers and pesticides, over the last decade, it has become a supplier of energy inputs. Therefore, resource should be integrate and use judiciously for the maximum resource use efficiency with “holistic triple bottom line approach” (social, economic and environmental aspect).

References


Recycling of Biomass for Composting and Vermicomposting in Organic based IFS
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The poor fertility of acid soils of North Eastern Hill Region coupled with lack of scientific knowledge of tribal farmers about the soil health management is the major bottleneck for getting potential yields. Farmers are gradually shifting from inorganic farming to eco-friendly organic farming system. According to the International Federation of Organic Agriculture Movements (IFOAM), organic farming is “a production system which sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects”. Organic agriculture is a whole systems approach which involves understanding and supporting processes that contribute to the four principles of health, ecology, fairness and care. Any material which is alive or once was alive is “organic.” All plants and animals, anything made from plants or animals, and any wastes generated by plants and animals are regarded as organic. In an Integrated Farming System, one components refuge should be others input concept. Recycling organic materials in most cases means composting. Compost and vermicompost are used as an important source of organic matter and nutrients in organic agriculture, and is also an important component of growing media for nurseries. Compost plays an important role in building a resilient farming system, by providing both the energy sources and the nutrients to sustain soil biodiversity. Resource poor tribal farmers usually depend on the within farm organic resources for organic production. There is a huge organic biomass in the hilly regions. Without converting this biomass in to compost, we cannot bring success to the organic farmers. Here we will discuss the rural or farm waste composting which will be useful for producing organic based composting in integrated farming system.

Classification of Manures
A. Bulky Organic Manures (contain low amount of plant nutrient)
   1. Compost: Rural compost, Town compost, Vermicompost etc.
   3. Sewage and sludge
B. Green manures: Leguminous plant and Non-leguminous plant
C. Concentrated Organic Manures
   1. Oil cakes. (Richest source of plant nutrient of all organic manures): edible oil cakes (mustard, groundnut, sesame, linseed etc.) and non-edible oil cakes (cakes from castor, neem, sunflower, mahua, karaja etc.)
   3. Fish products: Fish Meal
D. Guano: Manures from the excreta and dead bodies of marine birds
Recycling of Biomass through Composting

Composts are the end product of a process involving the breakdown of various materials (e.g. leaves, manure, food scraps) into a more usable form for the plants. This breakdown occurs because of the biological activity within your compost pile, bin, or tumbler. This returns nutrients and organic material to soil. Spring crops will decompose quickly if cut when they are still succulent or nitrogen fertilizer can be added to speed decomposition. The rural/farm compost contain about 0.4-0.8 % Nitrogen (N), 0.3-0.6 % P$_2$O$_5$ and 0.7-1.0 % K$_2$O. In an integrated farm, compost can be prepared from the waste materials available in the farm as follows:

(i) Cereals straws that are unsuitable for feeding of farm animals.
(ii) Farm weeds and grasses, water hyacinth etc.
(iii) Sugarcane leaves and trash, stalk of maize, jowar, bajra, etc.
(iv) Waste gunny bags, old cotton cloths, cellulose based wastes, papers etc.
(v) House /kitchen refuges and waste materials of vegetables, fruits, etc.
(vi) Waste materials of crops, mushroom spent straw wood ash etc.
(vii) Poultry/duck litter and urine soaked bedding materials from cattle shed.

Essential Requirements for Successful Composting

(i) **Bulk Organic Refuse**: Compost is generally prepared from the large quantities of waste materials and waste from cattle shed, and these organic refuse normally has high C:N ratio.
(ii) **Water**: If the compost pile is less than 50-60% moisture, composting may not be satisfactory.
(iii) **Air**: Decomposition of farm refuse is an oxidation process and occurs in the initial stages. The air may be introduced by turning the compost heaps at an interval of 10 to 15 days. The further decomposition should proceed anaerobically to minimise the loss of organic matter and Nitrogen.
(iv) **Suitable Starter**: The suitable starters like urine, soil, animal dung, sewage, sludge, activated substances, ADCO powder etc. Adco Process was introduced by Hutchinson and Richards in England in 1921. Adco powder is used as a starter @ 7.0 kg per 100 kg of dry waste product. The Adco Powder is suspected to be a mixture of (NH$_4$)$_2$SO$_4$ (27 kg), Superphosphate (13.5 kg), MOP (11.250 kg) and lime stone (22.5 kg). It is a very suitable method for making compost. The refuges decomposed within 4-5 months of composting and become good manure. But, turning is needed and availability is difficult.

Phages/stages of composting

1) **The mesophilic phase**: Compost bacteria combine carbon with oxygen to produce carbon dioxide and energy. Some of the energy is used by the microorganisms for reproduction and growth, the rest is given off as heat. When a pile of organic refuse begins to undergo the composting process, mesophilic bacteria proliferate, raising
the temperature of the composting mass up to 44°C (111°F). These mesophilic bacteria can include *E. coli* and other bacteria from the human intestinal tract, but these soon become increasingly inhibited by the temperature.

2) **Thermophilic phase:** The thermophilic bacteria take over in the transition range of 44°C-52°C (111°F-125.6°F) and can continue up to about 70°C (158°F). This heating stage takes place rather quickly and may last only a few days, weeks, or months. After the thermophilic heating period, the humanure will appear to have been digested, but the coarser organic material will not.

3) **Cooling phase:** After the thermophilic stage, there is still a lot of food in the pile. It takes many months to break down some of the more resistant organic material in compost such as lignin which comes from wood materials. During this phase, the microorganisms that were chased away by the thermophiles migrate back into the compost and get back to work digesting the more resistant organic materials. Fungi and macroorganisms such as earthworms and sowbugs that break the coarser elements down into humus. Lignins resist breakdown by thermophiles. However, other organisms, such as fungi, can break down lignin, given enough time; since they do not like the heat of thermophilic compost, they simply wait for things to cool down before beginning their job.

4) **Curing phase:** The final stage of the composting process is called the curing, aging, or maturing stage, and it is a long and important one. However, the curing, aging, or maturing of the compost is a critically important stage of the compost-making process. A long curing period (a year) adds a safety net for pathogen destruction. Many human pathogens only have a limited period of viability in the soil. Immature compost can be harmful to plants. Uncured compost can produce phytotoxins, can rob the soil of oxygen and nitrogen, and can contain high levels of organic acids.

![Figure 1: Stages of composting](image-url)
Methods of composting

A: (i) Indore-pit method (Aerobic and Passive)

An important advance in the practice of composting was made at Indore in India by Howard in the mid-1920s. The traditional procedure was systematized into a method of composting now known as the Indore method (FAO, 1980). All organic material wastes available on a farm are collected and stacked in a pile. Hard woody material are first spread on the road and crushed under tractors or bullock (<10%). Green and soft materials are allowed to wilt for two to three days to remove excess moisture and stacked layer wise (15 cm thick and 1.5 m high). The mixture of different kinds of organic material residues ensures a more efficient decomposition. The heap is then cut into vertical slices and about 20-25 kg is put under the feet of cattle in the shed as bedding for the night. The next morning, the bedding, along with the dung and urine and urine-earth, is taken to the pits where the composting is to be done. The compost pit (1 m deep, 1.5-2 m wide, near the cattle shed) should be at a level high enough to prevent entering rainwater (preferably temporary shed). The material brought from the cattle shed is spread in the pit in even layers of 10-15 cm. Slurry made from 4.5 kg of dung, 3.5 kg of urine-earth and 4.5 kg of inoculum from a 15-day-old composting pit is spread on each layer. Sufficient water is sprinkled over the material in the pit to wet it. The pit is filled in this way, layer by layer, and it should not take longer than one week to fill. The material is turned three times while composting (15 days +15 days +30 days and mixed thoroughly and moistened with water.

A: (ii) Indore heap method

During rainy seasons or in regions with heavy rainfall, the compost may be prepared in heaps above ground and protected by a shed. The pile is about 2 m wide at the base, 1.5 m high and 2 m long. The sides taper so that the top is about 0.5 m narrower than the base. A small bund is sometimes built around the pile to protect it from wind, which tends to dry the heap. The heap is usually started with a 20 cm layer of carbonaceous material. This is covered with 10 cm of nitrogenous material such as fresh grass, weeds or garden plant residues, fresh or dry manure or digested sewage sludge (until the pile is 1.5 m high) The pile is sometimes covered with soil or hay to retain heat and it is turned at intervals of 6 and 12 weeks. The heaps may be covered with thin plastic sheets to retain heat and prevent insect breeding. Most materials can be shredded by running a rotary mower over them several times. Where sufficient nitrogenous material is not available, a green manure or leguminous crop such as sun hemp is grown on the fermenting heap by sowing seeds after the first turning. The green matter is then turned in at the time of the second mixing. The process takes about four months to complete.

B. Bangalore method (Anaerobic and Passive)

This method of composting was developed at Bangalore in India in 1939 (FAO, 1980). It is recommended where night soil and refuse are used for preparing the compost. The
method overcomes many of the disadvantages of the Indore method, such as the problem of heap protection from adverse weather, nutrient losses from high winds and strong sun, frequent turning requirements, and fly nuisance. However, the time required for the production of finished compost is much longer. The method is suitable for areas with scanty rainfall. Trenches or pits about 1 m deep are dug; the breadth and length can vary according to the requirement. Site selection is as per the Indore method. The trenches should have sloping walls and a floor with a 90-cm slope to prevent waterlogging. Organic residues and night soil are put in alternate layers. After filling, the pit is covered with a layer of refuse of 15-20 cm. The materials are allowed to remain in the pit without turning and watering for three months. During this period, the material settles owing to reduction in biomass volume. Additional night soil and refuse are placed on top in alternate layers and plastered or covered with mud or earth to prevent loss of moisture and breeding of flies. After the initial aerobic composting (about eight to ten days), the material undergoes anaerobic decomposition at a very slow rate. It takes about six to eight months to obtain the finished product.

C. Coimbatore method (Anaerobic and Passive)
This method involves digging a pit (360 cm long × 180 cm wide × 90 cm deep) in a shaded area (length can vary according to the volume of waste materials available). Farm wastes such as straw, vegetable refuse, weeds and leaves are spread to a thickness of 15-20 cm. Wet animal dung is spread over this layer to a thickness of 5 cm. Water is sprinkled to moisten the material (50-60 percent of mass). This procedure is repeated until the whole mass reaches a height of 60 cm above ground. It is then plastered with mud, and anaerobic decomposition commences. In four weeks, the mass becomes reduced and the heap flattens. The mud plaster is removed and the entire mass is turned. Aerobic decomposition commences in at this stage. Water is sprinkled to keep the material moist. The compost is ready for use after four months.

D. Chinese rural composting – (Rapid, high temperature, aerobic)
This form of compost is prepared mainly from night soil, urine, sewage, animal dung, and chopped plant residues at a ratio of 1:4. The materials are heaped in alternate layers starting with chopped plant stalks and followed by human and animal wastes; water is added to an optimal amount. At the time of making the heap, a number of bamboo poles are inserted for aeration purposes. Once the heap formation is complete, it is sealed with 3 cm of mud plaster. The bamboo poles are withdrawn on the second day of composting, leaving the holes to provide aeration. Within four to five days, the temperature rises to 60-70 °C and the holes are then sealed. The first turning is usually done after two weeks and the moisture is made up with water or animal or human excreta; the turned heap is again sealed with mud. The compost is ready for use within two months.

E. Ecuador on-farm composting (Rapid, high temperature, aerobic)
Under this method, the animal manure: from cows, pigs, poultry, horses, donkeys, ducks, crop residues and agro-industrial wastes, ash and phosphate rock, wood cuttings, topsoil
from the forest or from an uncultivated or sparingly cultivated area freshwater. The raw materials are put in layers in the following sequence; layer of crop residues (20 cm); layer of topsoil (2 cm); layer of manure (5-10 cm). Ash or phosphate rock \((50 \text{ g/m}^2)\) is then spread on the surface, and freshwater is sprinkled on the material. Repeated until a height of about 1-1.2 m is reached. It is recommended to begin the heap by constructing a lattice of old branches, and to place two or three woodcuttings vertically along the lattice in order to facilitate ventilation. The heap should be \(2 \text{ m} \times 1-1.2 \text{ m} \times 1-1.2 \text{ m}\). Once a week, water should be added to the heap. After three weeks, the heap must be mixed to ensure that all materials reach the centre. During the process, the temperature rises to 60-70 °C, and most weed seeds and pathogens are killed. While it may take about two to three months to prepare the compost in a warm climate, in cold regions it could take five to six months.

**F. EM-based quick composting (Aerobic high temperature composting with inoculation)**

Effective micro-organisms (EM) consist of common and food-grade aerobic and anaerobic micro-organisms: photosynthetic bacteria, Lactobacillus, Streptomyces, Actinomycetes, Yeast, etc. The strains of the micro-organisms are commonly available from microbe banks or from the environment. There are no genetically engineered strains that are in use. Since 1999, seven small-scale organic fertilizer units have been using the EM-based quick production process in Myanmar (FAO, 2002). The raw materials for organic fertilizer production are: cow dung - 2 portions; rice husk - 1 portion; rice husk-charcoal - 1 portion; rice bran, milled - 1 portion; accelerator - 33 litres of EM solution or \(\text{Trichoderma} \) solution per pit. One litre of '\text{instant solution}' is made by mixing 10 ml of EM, 40 ml of molasses and 950 ml of water and leaving it for five to seven days, depending on temperature. The solution is then added to 1 litre of molasses and 98 litres of water to obtain 100 litres of ready-to-use EM solution. This amount is enough for three pits \((l=180 \text{ cm}, \text{W}=120 \text{ cm}, \text{d}=90 \text{ cm})\). The EM solution functioning as accelerator reduces the composting period from 1-3 months.

**G. Composting weeds**

This method has been developed for composting weeds such as parthenium, water hyacinth \((Eichornia crassipes)\), cyperus \((Cyperus rotundus)\) and cynodon \((Cynodon dactylon)\). The materials required are: 250 g of \(\text{Trichoderma viride} \) and \(\text{Pleurotus sajor-caju} \) consortia, and 5 kg of urea. An elevated shaded place is selected, or a thatched shed is erected. An area of 500 cm \(\times\) 150 cm is marked out. The material to be composted is cut to 10-15 cm in size. About 100 kg of cut material is spread over the marked area. About 50 g of microbial consortia is sprinkled over this layer. About 100 kg of weeds are spread on this layer. One kilogram of urea is sprinkled uniformly over the layer. This process is repeated until the level rises to 1 m. Water is sprinkled as necessary to maintain a moisture level of 50-60 percent. Thereafter, the surface of the heap is covered with a thin layer of soil. The pile requires a thorough turning on the 21\textsuperscript{st} day. The compost is ready in about 40 days.
### Table 1. Salient features of selected small-scale aerobic composting techniques

<table>
<thead>
<tr>
<th>Method</th>
<th>Substrate size reduction</th>
<th>Turnings at intervals of (days)</th>
<th>Added aeration provision</th>
<th>Microbial inoculation</th>
<th>Supporting microbial nutrition</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indore pit</td>
<td></td>
<td>+15, +30, +60</td>
<td>Inoculum from old pit</td>
<td></td>
<td></td>
<td>4 months</td>
</tr>
<tr>
<td>Indore heap</td>
<td>Shredded</td>
<td>+42, +84</td>
<td></td>
<td></td>
<td></td>
<td>4 months</td>
</tr>
<tr>
<td>Chinese pit</td>
<td>Shredded</td>
<td>+30, +60, +75</td>
<td></td>
<td>Superphosphate</td>
<td></td>
<td>3 months</td>
</tr>
<tr>
<td>Chinese high temperature compost</td>
<td>Shredded</td>
<td>+15</td>
<td>Aeration holes in heap through bamboo poles/maize stalks</td>
<td>Superphosphate</td>
<td></td>
<td>2 months</td>
</tr>
<tr>
<td>Ecuador on-farm composting</td>
<td></td>
<td>+21</td>
<td>Lattice of old branches/poles at heap base</td>
<td></td>
<td></td>
<td>2-3 months in summer; 5-6 months in winter</td>
</tr>
<tr>
<td>Berkley rapid composting</td>
<td>Shredded to small size</td>
<td>Daily or alternate day turning</td>
<td></td>
<td></td>
<td></td>
<td>2 weeks with daily turning &amp; 3 weeks with alternate day turning</td>
</tr>
<tr>
<td>North Dakota State University hot composting</td>
<td>Shredded</td>
<td>+3 or +4</td>
<td>4-5 holes punched in centre of pile</td>
<td>0.12 kg N per 90 cm dry matter</td>
<td></td>
<td>4-6 weeks</td>
</tr>
<tr>
<td>EM-based quick composting</td>
<td></td>
<td>+14, +21</td>
<td>EM</td>
<td>Molasses</td>
<td></td>
<td>4-5 weeks</td>
</tr>
<tr>
<td>IBS rapid composting (Institute of Biological Sciences)</td>
<td>Shredded</td>
<td>+7, +14, then every 2 weeks</td>
<td>Raised platform ground/perforated bamboo trunks</td>
<td>Trichoderma a sp.</td>
<td></td>
<td>3-7 weeks</td>
</tr>
</tbody>
</table>

### Factors affecting aerobic composting

The quality of compost largely depends on the process of composting. It is largely a biological process in which aerobic and anaerobic microorganisms decompose organic matter and lower the Carbon-Nitrogen ratio of the refuse. Here are some points to be considered while composting. An understanding of the principles and technical options and their appropriate application may be helpful in providing the optimal environment to the compost pile.

**Aeration**: Aerobic composting requires large amounts of O₂, particularly at the initial stage. Where the supply of O₂ is not sufficient, the growth of aerobic micro-organisms is limited, resulting in slower decomposition. Moreover, aeration removes excessive heat, water vapour and other gases trapped in the pile. Heat removal is particularly important.
in warm climates as the risk of overheating and fire is higher. Therefore, good aeration is indispensable for efficient composting. It may be achieved by controlling the physical quality of the materials (particle size and moisture content), pile size and ventilation and by ensuring adequate frequency of turning.

**Moisture:** Moisture is necessary to support the metabolic activity of the micro-organisms. Composting materials should maintain moisture content of 40-65 percent. Where the pile is too dry, composting occurs more slowly, while moisture content in excess of 65 percent develops anaerobic conditions. In practice, it is advisable to start the pile with moisture content of 50-60 percent, finishing at about 30 percent.

**Nutrients:** Micro-organisms require C, N, phosphorus (P) and potassium (K) as the primary nutrients. Of particular importance is the C:N ratio of raw materials. The optimal C:N ratio of raw materials is between 25:1 and 30:1 although ratios between 20:1 and 40:1 are also acceptable. Where the ratio is higher than 40:1, the growth of micro-organisms is limited, resulting in a longer composting time. A C:N ratio of less than 20:1 leads to underutilization of N and the excess may be lost to the atmosphere as ammonia or nitrous oxide, and odour can be a problem. The C:N ratio of the final product should be between about 10:1 and 15:1.

**Temperature:** The process of composting involves two temperature ranges: mesophilic and thermophilic. While the ideal temperature for the initial composting stage is 20-45 °C, at subsequent stages with the thermophilic organisms taking over, a temperature range of 50-70 °C may be ideal. High temperatures characterize the aerobic composting process and serve as signs of vigorous microbial activities. Pathogens are normally destroyed at 55 °C and above, while the critical point for elimination of weed seeds is 62 °C. Turnings and aeration can be used to regulate temperature.

**Pile size and porosity of the material:** Where the pile or wind-row is too large, anaerobic zones occur near its centre, which slows the process and too small lose heat quickly and may not achieve a temperature high enough to evaporate moisture and kill pathogens and weed seeds. Heavy weights should not be put on top and materials should be kept as loose as possible. With a view to minimizing heat loss, larger piles are suitable for cold weather. However, in a warmer climate, the same piles may overheat and in some extreme cases (75 °C and above) catch fire.

**Shredding:** Downsizing, or chopping up the materials, is a sound and widely-practised technique. It increases the surface area available for microbial action and provides better aeration. This technique is particularly effective and necessary for harder materials such as wood.

**Lignin content:** Lignin is one of the main constituents of plant cell walls, and its complex chemical structure makes it highly resistant to microbial degradation (Richard, 1996). This nature of lignin has two implications. One is that lignin reduces the bioavailability of the other cell-wall constituents, making the actual C:N ratio (viz. ratio of biodegradable C to
N) lower than the one normally cited. The other is that lignin serves as a porosity enhancer, which creates favourable conditions for aerobic composting. Therefore, while the addition of lignin-decomposing fungi may in some cases increase available C, accelerate composting and reduce N loss, in other cases it may result in a higher actual C:N ratio and poor porosity, both of which prolong composting time.

**Polyphenols:** Polyphenols include hydrolysable and condensed tannins make physically or chemically less accessible to decomposers. Soluble condensed and hydrolysable tannins react with proteins and reduce their microbial degradation and thus N release. Polyphenols and lignin are attracting more attention as inhibiting factors. Palm et al. (2001) suggest that the contents of these two substances be used to classify organic materials for more efficient on-farm natural resource utilization, including composting.

**pH value:** Although the natural buffering effect of the composting process lends itself to accepting material with a wide range of pH, the pH level should not exceed 8. At higher pH levels, more ammonia gas is generated and may be lost to the atmosphere.

**Turning:** Once the pile is formed and decomposition starts, the only technique for improving aeration is turning. Frequency of turning is crucial for composting time. While the Indian Coimbatore method (turning once) reduces the time to four months while Berkley rapid composting method needs daily turning to complete the process in two weeks. However, turning too frequently might result in a lower temperature.

**Inoculation:** While some composters find improved aeration enough for enhanced microbial activities, others may need inoculation of micro-organisms. Inoculum organisms utilized for composting are mainly fungi such as *Trichoderma* sp. and *Pleurotus* sp. Use of effective micro-organisms' (EMs) based quick compost production and economical. The inoculums are an affordable choice for those with access to the market and also for resource-poor farmers. The production cost could be reduced by purchasing the commercial product and multiplying it on the farm.

**Supplemental nutrition:** The techniques mentioned above often need to be complemented by the provision of nutrients. One of the most common practices is to add inorganic fertilizers, particularly N, in order to modify a high C:N ratio. Similarly, P is sometimes applied as the C:P ratio of the material mix is also considered important (the ratio should be between 75:1 and 150:1). When micro-organisms are inoculated, they require sugar and amino acids in order to boost their initial activities; molasses is often added for this purpose.

**Lime treatment:** By adding organic wastes such as sawdust, wood shavings, coir pith, pine needles, and dry fallen leaves, while preparing organic waste mixtures for composting, one can ensure that the compost produced contains sufficient and long-lasting humus. However, gardeners often find that where they use lignin-rich plant materials, the compost does not ripen rapidly. A technique for making good compost from hard plant materials involves mixing lime in a ratio of 5 kg per 1000 kg of waste.
material. Lime can be applied as dry powder or after mixing with a sufficient quantity of water. Treatment with lime enhances the process of decomposition of hard materials. Liming can enhance the humification process in plant residues by enhancing microbial population and activity and by weakening lignin structure. It also improves the humus quality by changing the ratio of humic to fulvic acids and decreases the amount of bitumen, which interferes with the decomposition process. Instead of lime, powdered phosphate rock can be used in a ratio of 20 kg per 1000 kg of organic waste. Phosphate rock contains a lot of lime. The phosphates and micronutrients contained in phosphate rock make composts rich in plant nutrients. Coir pith is a waste from the coir industry. To compost 1 tonne of coir pith, the materials required are: five spawn bottles (250 g) of *Pleurotus* sp. and 5 kg of urea.

**Compost enrichment**

Farm compost is poor in P content (0.4-0.8 percent). Addition of P makes the compost more balanced, and supplies nutrient to micro-organisms for their multiplication and faster decomposition. The addition of P also reduces N losses. Compost can be enriched by:

- Application of superphosphate, bonemeal or phosphate rock (Ramasami, 1975): 1 kg of superphosphate or bonemeal is applied over each layer of animal dung. Low-grade phosphate rock can also be used for this purpose.
- Use of animal bones: these can be broken into small pieces, boiled with wood ash leachate or lime water and drained, and the residue applied to the pits. This procedure of boiling bones facilitates their disintegration. Even the addition of raw bones, broken into small pieces and added to the pit, improves the nutrient value of compost significantly.
- Wood ash waste can also be added to increase the K content of compost.
- Addition of N-fixing and P-solubilizing cultures (IARI, 1989): The quality of compost can be further improved by the secondary inoculation of *Azotobacter*, *Azospirillum lipoferum*, and *Azospirillum brasilens* (N-fixers); and *Bacillus megaterium* or *Pseudomonas* sp. (P solubilizers). These organisms, in the form of culture broth or water suspension of biofertilizer products, can be sprinkled when the decomposing material is turned after one month. By this time, the temperature of the compost has also stabilized at about 35 °C. As a result of this inoculation, the N content of straw compost can be increased by up to 2 percent. In addition to improving N content and the availability of other plant nutrients, these additions help to reduce the composting time considerably.

**Recycling of biomass through vermicomposting**

Vermicomposting is the biotechnological process of using worms (“vermi” is Latin for “worm”) to breakdown the organic wastes into nutrient-rich compost. The process is faster than composting; because the material passes through the earthworm gut with a
significant but not yet fully understood transformation takes place, whereby the resulting earthworm castings are rich in microbial activity. This method of composting is gaining importance due to its high nutrient contents and the presence of growth promoting substances like plant growth regulators, vitamins, chelating agents etc., and fortified with pest repellence attributes as well. Moreover, it contains several beneficial microorganisms which help in activities like nitrogen fixation, phosphorous solubilisation and suppression of harmful microorganisms in the crop fields. In horticulture crops especially fruit orchards depending on the stage of growth, vermicompost use of 1-20 kgs per plant can give better yield.

Table 2: range of chemical composition of vermicompost is given below.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>RANGE OF VALUE</th>
<th>PARAMETER</th>
<th>RANGE OF VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.0-7.5</td>
<td>Sodium (%)</td>
<td>0.02 - 0.30</td>
</tr>
<tr>
<td>Organic Carbon (%)</td>
<td>30</td>
<td>Sulphur (%)</td>
<td>TRACES TO 0.40</td>
</tr>
<tr>
<td>Nitrogen (%)</td>
<td>0.90</td>
<td>Iron (%)</td>
<td>0.3-0.7</td>
</tr>
<tr>
<td>Phosphorus (%)</td>
<td>1.00-1.90</td>
<td>Zinc (%)</td>
<td>0.02 - 0.03</td>
</tr>
<tr>
<td>Potassium (%)</td>
<td>1.00-1.50</td>
<td>Manganese (%)</td>
<td>TRACES TO 0.40</td>
</tr>
<tr>
<td>Carbon : Nitrogen</td>
<td>1</td>
<td>Copper (%)</td>
<td>0.002 - 0.010</td>
</tr>
<tr>
<td>Calcium (%)</td>
<td>2.0 - 4.0</td>
<td>Aluminium (%)</td>
<td>TRACES TO 0.07</td>
</tr>
<tr>
<td>Magnesium (%)</td>
<td>0.4-0.7</td>
<td>Boron (%)</td>
<td>0.003 - 0.007</td>
</tr>
</tbody>
</table>

Types of earthworms

There are about 350 species of earthworms in India with various foods and borrowing habits. Worms like *Eisenia fetida*, *Eudritus engineae*, *Perinyx excaratus* and *Polypheretima elongata* are used in vermicomposting. They are effective bio-converters of organic wastes. *Eisenia fetida* worms are used for vermicomposting of both domestic and industrial organic waste. They are native to Europe, but have been introduced to every other continent except Antarctica. They have groups of bristles (called setae) to push themselves forward or backward. Out of the four most popular species of earthworm *Eisenia foetida* have been found most suitable species under agro-climatic condition of Manipur. Earthworms are of two types on the basis of their food habits as follows:

i) *Detrivorus saprophages*: This type of earthworms’ lives on the refuges or dead plant roots and other parts of the plant or cow dung of mammals and they remain on the upper surface of the soil or near it. Example: *Eisenia fetida, Perinyx excavatus, Eudritus engineae, Lampito mauritii, Octochaetona surensis* etc.

ii) *Geophages saprophages*: This type of earthworm ingest the soil mixed with organic matter. They intake the edible materials from deep region of the soil eg. *Octochaetona thurstoni* etc.

Steps for vermicomposting

Vermicomposting process involves three steps (1) Pretreatment of composting materials (2) Composting and (3) Residue disposal. Agricultural wastes may be required to cut into
smaller pieces for enhancing decomposition process. The separated material should be spread in a layer of maximum of 1 foot to expose to sun for a day. To control insect pest infestation, if any, neem formulation can be used. This helps in killing some of the unwanted organisms and removes foul smell. Then the material should be mixed with cowdung slurry, made a heap covered with clothes or left on ground for 4/5 weeks for partial decomposition. This partially decomposed material is now ready for vermicomposting.

![Steps during Vermicomposting](image)

Figure 2: Steps during Vermicomposting (a) cutting of biomass (b) Predecomposition (c) Application of cowdung slurry (d) Worm addition/composting (e) Short exposing to sunlight (f) Sieving

**Methods of vermicomposting**

1. *Pits below the ground*: Pits made for vermicomposting are 1 m deep, 1.5 m wide and 2 m long. The length varies as required. At the bottom of the pit, a vermibed has to be created for the earthworms. This is done by placing 15-20 cm thick layer of good loamy soil above a thin layer (*i.e.*, 5 cm) of broken bricks and sand. Earthworms are introduced in the soil layer where they will inhabit. About 100 earthworms will constitute an optimum inoculating density for the above size of the pit. The vermibed has to be kept moist without flooding. Handful lumps of fresh cattle dung are then placed at random over the vermibed. The compost pit is then layered to about 5 cm with dry leaves or hay. The pit may be covered with coconut or palmyrah leaves to protect worms from birds. After 30 days of decomposition, wet organic wastes of animal and/or plant origin are spread over the partially decomposed organic layer to a thickness of about 5 cm. This has to be repeated twice a week. All these organic wastes may be turned over or mixed periodically using a hand tool without disturbing the vermibed in which the worms live.
Addition of organic wastes can be repeated till the pit is nearly full. The pit has to be kept moist for another 30-45 days. During this period, the material in the pit has to be turned over occasionally without disturbing the

2. **Heaping above the ground**: The waste material is spread on a polythene sheet or cemented floor and then covered with cattle dung.

3. **Tanks above the ground**: Tanks made up of different materials such as normal bricks, hollow bricks, asbestos sheets and locally available rocks are adopted for vermicompost preparation. At the base of pit/tank, a layer of broken bricks is to be placed, followed by coarse sand. The thickness of layer should range between 5-7.5 cm well suited for drainage of excess water. At second layer, chopped waste materials should be placed. The thickness of layer should be about 30 cm well suited for aeration. Third layer should be of 15-30 days old cow dung with the thickness of about 20-30 cm which acts as reserve food for earthworms. Fourth layer or top layer should have pretreated i.e. partially decomposed waste up to thickness of 30-40 cm. Earthworms are introduced in between the layers @ 350 worms per m$^3$ of bed volume and covered with moist gunny bag. The beds are maintained at about 40-50% moisture content and a temperature of 20-30° C by sprinkling water over the beds. If moisture is high, dry cowdung or leaf litter should be mixed in the substrate. The pH of the substrate should be between 6.8-7.5. Sprinkling of water should be stopped before 3-4 days of harvesting to allow the worms to go down because of the drying of surface layers and the compost is then harvested, dried in shade and packed.

Nowadays low cost HDPE woven vermibed (12x4x2 feet) can replace the cemented structures. It is a tough new generation vermiculture bed for producing superior grade vermicompost and vermiwash, rearing earthworms for organic farming. These beds represent the future in modern compost technology, which is smart choice for all organic agriculture that benefit from the higher yields resulting from vermicompost. Although, farmers have the idea that, vermicompost is an excellent, nutrient rich organic fertilizer and soil conditioner which reduce farmer’s expenses on chemical fertilizer, but poor farmers can not afford the capital investment for constructing the cemented structures.
Vermiwash

Vermiwash is a liquid fertilizer collected after passage of water through a column of worm activation. It can be used as foliar spray after diluting with water. It can also be used as pesticides if mixed with 10% diluted urine of cow.

Economics (approximate)

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>i) Cost of Tank (3m x 2m x 0.75m)</td>
<td>Rs. 30,000</td>
</tr>
<tr>
<td>ii) Yield of vermicompost (per 3 month)</td>
<td>900 kg</td>
</tr>
<tr>
<td>iii) Yield of earthworms</td>
<td>66,000 numbers</td>
</tr>
<tr>
<td>iv) Gross return</td>
<td>Rs. 82,200/-</td>
</tr>
<tr>
<td>v) Net return</td>
<td>Rs. 52,200/-</td>
</tr>
</tbody>
</table>

(Official rate of sale: Vermicopost Rs. 16200 @Rs.18 per kg and earthworm - Rs. 66,000 @Rs. 1.0)

Care and maintenance:

- The unit should be covered with wet gunny to reduce loss of moisture.
- To control ants and other insects, turmeric powder or neem cake should be spread over and around the unit. Leaves of lantana camara can also be used around the tank as an alternative.
- The materials collected for vermicomposting should be free from non-degradable materials like plastics, stones, glass, ceramics and metals.
- The heap should be thoroughly mixed at an interval of 30 days.
- The bed should be under roof to prevent direct sun and rain.

Integrating traditional composting and vermicomposting

Problems associated with traditional thermophilic composting relate to, long duration of the process, frequent turning of the material, material size reduction to enhance the surface area, loss of nutrients during the prolonged process, and the heterogeneous resultant product. However, the main advantage of thermophilic composting is that the temperatures reached during the process are high enough for an adequate pathogen kill. In vermicomposting, the earthworms take over both the roles of turning and maintaining the material in an aerobic condition, thereby reducing the need for mechanical operations. In addition, the product (vermicompost) is homogenous. However, the major drawback of the vermicomposting process is that the temperature is not high enough for an acceptable pathogen kill. Whereas in traditional thermophilic composting the temperatures exceed 70 °C, the vermicomposting processes must be maintained at less than 35 °C. A study has examined the possibility of integrating traditional thermophilic composting and vermicomposting. The two approaches (i) pre-composting followed by vermicomposting; and (ii) pre-vermicomposting followed by composting. A comparison was made with vermicomposting alone (duration: 56 days). The results indicated that the
combination of the two processes shortened the stabilization time and improved product quality (was four weeks). Furthermore, the resultant product was more stable and consistent, had less potential impact on the environment, and met pathogen reduction requirements (Ndegwa and Thompson, 2001).

**Do NOT compost these materials:**

1. Plants infected with disease or a severe insect attack where eggs could be preserved or where the insect themselves could survive in spite of the compost pile's heat (examples are apple scab, aphids and tent caterpillars).
2. Ivy, succulents and certain pernicious weeds such as morning glory and buttercups; and grasses which spread by rhizomes such as quack grass. These may not be killed by the heat of decomposition and can choke out other plants when compost is used in the garden.
3. Cat, dog and bird manures, which contain pathogens harmful to human. These pathogens are not always killed in the heat of the compost pile.
4. Meat and fish leftovers, bones, or greasy fatty foods such as oils, butter, and cheeses.
5. Piles made entirely of waxy leaves such as rhododendron and English Laurel, or pine needles break down very slowly. Try composting small amounts of these mixed with other materials, shred them first or use them as mulch.
6. Diseased or insect-infested plants should not be turned in.

**Reference**

FAO. 2003. Land and water discussion paper 2. Viale delle Terme di Caracalla, 00100 Rome, Italy
Green manuring for improving soil health and crop productivity

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¹ICAR-RC for NEH Region Manipur Centre Imphal, Manipur; ²B.R.D. (P.G.) College Deoria, Uttar Pradesh

Among all the concerns related to stagnation in food production, degradation of soil quality due to excessive use of fertilizers is burgeoning. Though, the chemical fertilizers are a major source of nutrients to crops, use of chemical fertilizers alone for a long period of time leaves unfavorable effects on soil physical, chemical and biological property and environment. The integration of nutrients results in improved efficiency of chemical fertilizers and better cost benefit relationship. Organic manures though low nutrient carrying material but leave a favorable effect on soil properties. Integrated Nutrient Management (INM) refers to the maintenance of soil fertility and of plant nutrient supply at an optimum level for sustaining the desired productivity through optimization of the benefits from all possible sources of organic, inorganic and biological components in an integrated manner. Integrated Nutrient Management improves soil health in long run and reduces the demand for chemical fertilizers. It ensures the concept of sustainability in agriculture. The benefits of Integrated Nutrient Management approach need to be fully harnessed keeping in view the demand of food for increasing population, dwindling supplies and increasing cost of fossil fuels. Integrated Nutrient Management is flexible approach to minimize the use of chemicals and maximize the efficiency of production. The concept paves the ways for optimization of all available sources of plant nutrients to improve soil fertility.

Technological needs: Unless the farmers are exposed to proper training and demonstration for adoption of location specific and need based technology, the task seems tough. The best prolific knowledge in agriculture needs to be percolated down to the farmers’ through participatory mode of research. Krishi Vigyan Kendras (KVKs) have been promoting agriculture through assessment, refinement, and dissemination of agriculture technologies and products at district level. Effective extension mechanisms require togetherness of scientists and farmers at district level and in this connection our KVKs will play a crucial role in the form of knowledge resource center. Now a day’s Government has also emphasized Farmers as “FIRST” in country where FIRST stands for Farmer, Innovations, Resources, Science and Technology. Therefore, concentrated efforts are to be made for the interest, aspiration and expectations of farmers. Intensive cultivation, growing exhaustive crops, use of unbalanced and inadequate fertilizers accompanied with restricted organic matter recycling (FYM, bio fertilizers and green manures) back in soil have made soils deficient not only in nutrients but also deteriorated soil quality, resulting in to decline in crop response to recommended doses of fertilizer. Increasing population load and degrading environmental conditions have been influencing the long term sustainability of the soil resource. All agricultural activities are
directly or indirectly affected by how the “soil is handled”, managing soils is a formidable
test to ensure productivity, profitability and national food security. The United
Nations Millennium Development Task Force on hunger made “soil health enhancement”
as one of the five recommendations for increasing agricultural productivity and fight
hunger in India as a component of millennium development goals (MDGs). Major issues
of soil health in Indian context include physical degradation, caused by compaction,
chemical degradation due to wide multi nutrient deficiency, higher nutrient turn over in
soil plant system coupled with low and imbalanced fertilizer use and insufficient input of
organic source resulting into poor nutrient use efficiency, biological degradation due to
organic matter depletion and loss in soil flora and fauna. The inadequate and imbalanced
fertilizer use has created wide spread nutrient deficiency and deterioration in soil health.
Microbial culture with indigenous sources of organic matter can help in increasing
nutrient use efficiency and crop productivity along with improvement in soil quality.

Strategies adopted to promote soil health and crop production:

**Green manuring for rice-wheat and mustard cropping systems:** Dhaincha (*Sesbania
spp.*), a green manure crop has long been known for its benefits of supplying fixed
atmospheric nitrogen and for its overall beneficial effects in improving soil health.
Despite known benefits, the practice of green manuring could not be adopted extensively
by the farmers. The main reason for this is non-introduction of *Sesbania* (Dhaincha) as
green manure in previous time, lack of awareness of green manuring, emphasis on major
crop production rather than nutrition of soils in Kharif season. More so, a farmer may not
be able to practice green manuring in the traditional manner at the cost of main crop in
Kharif season. Experiences reveal that farmers are reluctant in adoption of green
manuring practice at the cost of main crop in Kharif season because they have lack of
knowledge and techniques of green manuring. And more so, growing period of both the
crops overlap and require the same season for growing in same time. To improve the
productivity and better uptake of nutrients by grain, balanced supply of plant nutrients
through inclusion of summer green manuring in rice-wheat sequence seems more fruitful
rather than options available in rice-wheat cropping areas. Further, introduction of
summer green manuring having exact match with time frame available between harvest
of wheat crop and transplanting of rice is supposed to be third alternative for improving
soil health of rice-wheat cropping system (RWCS) in *Indo-Gangetic* plains under assured
irrigated conditions. Keeping these facts in mind, the three summer green manure crops
viz. Green gram (*PhaseolusaureusRoxb*), Sun hemp (*Crotalaria juncea Linn*) and Dhaincha
(*Sesbania aculeateaPoir*) were grown to study their effect on grain yield, nutrient content
in plant and their uptake by grain during 2003 to 2006 and pool data of the results have
discussed and summarized here
Field experiments at Banaras Hindu University (2006-2008) having twenty treatment with three legume crops viz. Green gram (*Phaseolusaureus*Roxb), Sun hemp (*Crotalaria juncea* Linn), Dhaincha (*Sesbania aculeate* Poir) and one fallow with N levels (00, 30, 60, 90 and 120 kg ha$^{-1}$) with three replications in split plot design were planned and executed. Summer Green gram in mid of April and Sun hemp and Dhaincha in mid of May were sown in field. The green manure crops were fertilized with 40 kg P$_2$O$_5$ and incorporated into field at suitable time. Rice crop was transplanted at 20x10 cm spacing and basal application of 60 kg P$_2$O$_5$ and 60 kg K$_2$O ha$^{-1}$ through single super phosphate and potassium chloride was done. Further, the rice crop received N doses as per
treatments through urea at the rate of 50% at transplanting 25% at tillering and 25% at panicle initiation stage.

**Nutrient potential of summer green manures:** The amount of green matter added to soil through green gram, sun hemp and dhaincha was 17.30, 32.65 and 35.55 t ha\(^{-1}\) respectively. Dry matter addition capacity of these summer green manure (SGM) crops was found to be 3.94, 5.87 and 5.71 t ha\(^{-1}\) respectively. The N, P and K gain to soil through these SGM crop was 79.6, 126.8 and 120.5 kg ha\(^{-1}\) respectively. The C: N ratio of this SGM Crops was also found to be ideal for rapid decomposition in soil.

**Table1: N, P and K contribution through different green manures**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Green Gram</th>
<th>Sun hemp</th>
<th>Dhaincha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green matter (t ha(^{-1}))</td>
<td>17.30</td>
<td>32.65</td>
<td>35.55</td>
</tr>
<tr>
<td>Dry matter (t ha(^{-1}))</td>
<td>3.94</td>
<td>5.87</td>
<td>5.71</td>
</tr>
<tr>
<td>N (g kg(^{-1}) dry weight basis)</td>
<td>20.2</td>
<td>21.6</td>
<td>21.0</td>
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<tr>
<td>P (g kg(^{-1}) dry weight basis)</td>
<td>4.4</td>
<td>4.6</td>
<td>4.5</td>
</tr>
<tr>
<td>K (g kg(^{-1}) dry weight basis)</td>
<td>25.2</td>
<td>22.2</td>
<td>24.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>N P K Contribution through green manures (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
</tr>
<tr>
<td>79.6</td>
</tr>
<tr>
<td>126.8</td>
</tr>
<tr>
<td>120.5</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
</tr>
<tr>
<td>17.3</td>
</tr>
<tr>
<td>27.0</td>
</tr>
<tr>
<td>31.4</td>
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<tr>
<td>Potassium (K)</td>
</tr>
<tr>
<td>98.5</td>
</tr>
<tr>
<td>130.3</td>
</tr>
<tr>
<td>137.6</td>
</tr>
</tbody>
</table>

*Above ground portion (Mean of two years)
Rice-Wheat grain yield: Maximum yield was harvested from the plot receiving green manuring along with recommended dose of N (120 kg ha⁻¹) followed by 90, 60 and 30 kg N ha⁻¹ during both the years of cropping. Sun hemp incubated treatment produced highest yield of rice followed by Dhaincha and Green gram during the course of study, while in case of wheat, Dhaincha treated plot registered highest grain yield followed by Sun hemp and Green gram respectively. Narrow C:N ratio of Sun hemp (16.1) as compared to Dhaincha (16.4) leading to quick mineralization might have released nutrients at faster rate resulting in to higher yield of rice in Sun hemp incubated plot than Dhaincha incubated field. Further, higher number of tillers and test weight resulted in higher grain yield of rice and wheat due to significant improvement in wet soil NH₄-N and oxidized soil NO₃-N at the different growth stages of crop.

Micronutrients content and their uptake: The green manures crop are comparatively deep rooted and have more mining capacity to nutrients especially of micronutrients which after decomposition leave micronutrients in plough layer depth. The finding of the study indicated that the copper, zinc, iron and manganese content at different stages of crop and grain increased due to green manuring as the plot accumulated higher amount of micronutrients as compared to fallow plots. The copper and zinc content in rice were higher in sun hemp incorporated plot followed by Dhaincha fed plots while iron and manganese contents were maximum in Dhaincha grown field followed by sun hemp treated plot. In case of wheat crop, copper, zinc, iron and manganese were found to be higher in Dhaincha grown field followed by sun hemp manured plots with N applied through urea. Green manures resulted in to marked improvement in nutrients concentration in rice and wheat crop especially of NPK, Fe, Mn, and Zn over the fellow plots. The green manures after decomposition release both macro and micro nutrients which become available to plots and thus increased the content and their uptake by crops. The production of certain organic compounds during decomposition might have been related to chelated formation with metal micronutrients and consequently higher uptake of these chelated forms by plants. Organic matter itself also acts as an important secondary source of micronutrients. Micronutrients made complex with organic section
and resulted in more uptake of them by crops. Over all the results of study revealed that inclusion of summer green manures in rice-wheat cropping sequence has been beneficial in improving soil properties, nutrient uptake by grain and crop yield.

Soil Parameters:

**Bulk density (BD):** BD of soil got decreased significantly in Sun hemp supplied plot followed by Dhaincha and Green gram after harvest of rice, but in case of wheat significant reduction in BD occurred in Dhaincha fed plot followed by Sun hemp and Green gram either alone or in combination with fertilizers after harvest. The variation in C: N ratio of sun hemp (16.1) and Dhaincha (16.4) might have affected the rate of decomposition of green manures in soil. Sun hemp having narrow C:N ratio (16.1) might have decomposed faster thereby decreasing the BD of soil whereas, wider C:N ratio of Dhaincha (16.4) than Sun hemp consumed more time and showed the reduction in BD of soil after harvest of wheat. During decomposition process of organic matter various polysaccharides and humus are produced which may be responsible for binding the soil particiles resulting in more stable aggregates and causing reduction in bulk density. Significant reduction in bulk density is closely related with increased cumulative infiltration. Further, reduction in bulk density also occurs due to relatively higher organic matter content in soil which would have improved porosity of such soil. Decrease in BD may occur directly by dilution of soil matrix with a less dense material or indirectly by improving aggregate stability.

**Changes in pH and EC of Soil:** After harvest of rice and wheat crop addition of green manure along with fertilizer N reduced pH and increased electrical conductivity (EC) of soil as compared to control plot. Decrease in pH was greater in treatment receiving dhaincha as summer green manure followed by Sunhemp and Green gram respectively. Green manuring affects soil pH in two ways by producing organic acids and CO₂ during decomposition which can furnish protons to soil inducing a decrease in pH. Green manure crops produce sap acid during decomposition consequently reducing soil pH. Generally, it is noticed that little or no change in EC occurs by applying organic manures because even with fertilizers (being soluble salts) the increase in EC has been short lived. Under water logged conditions EC of soil solution increases with time, reaches a peak and then decrease. Addition of green manure would accelerate the decrease in Eh and accumulation of CO₂ thereby, release of large amount of ions (Fe^{2+}, Mn^{2+}, CO₃ etc.) in to soil solution and increase in EC. Data pertaining to EC showed that EC of the soil was significantly higher in green mannered plus fertilizer supplied plots. CO₂ evolution study conducted at field capacity up to one month of incubation at 30°C showed that summer green manure treated soil had higher respiration rates than that of fertilizer supplied indicating higher carbon status in green manured soil after harvest of crop. The increase in organic carbon could be attributed to the addition of organic matter through green manures.
Changes in organic carbon and CEC of soil: Organic carbon and cation exchange capacity status of soil after harvest of rice and wheat shows that summer green manuring along with fertilizer N through urea increased organic carbon and cation exchange capacity of soil as compared to control plot. Generally it is accepted that green manures maintain or increase organic matter or increase soil N levels but not both simultaneously. In present study addition of summer green manure along with fertilizer N increased organic carbon significantly over control. Highest addition occurred in Sun hemp treated plot followed by Dhaincha and Green gram. The maintenance or accumulation of organic matter in soil is dependent on a number of factors e.g. chemical natures of added material, soil and climatic factors affecting microbial and cultural practices. Generally, CEC of soil is governed by kind and nature of organic colloids, humus, iron and aluminum oxides. CEC of soil increased due to improvement in organic matter content of soil. Addition of organics along with fertilizer increased the CEC of soil over control followed by application of full recommended dose of fertilizer.

Green manures in mustard cropping system: Three On Farm Trials (OFT) on green manuring for assessment of their effects on mustard yield and Sodic soil quality were conducted at farmer’s field during 2011-2014 in selected villages of Newai and Todaraisingh Tehsil of Tonk district Rajasthan. OFT treatments comprised as T_1: farmer’s practice-FP, T_2: Recommended POP for mustard (Gypsum 50% GR + FYM+ RDF), T_3: Gypsum 50% GR + RDF + Green gram, T_4: Gypsum 50% GR + RDF + Sesbania (Dhaincha) and T_5: Gypsum 50% GR + RDF + Crotalaria (Sanai) as technological options. Three years results of OFT revealed that technological options T_4 and T_5 registered significantly higher mustard yield even over FP and POP treatments whereas T_3 (Gypsum 50% GR + RDF + Green gram) could registered significantly higher yield only over T_1. Higher monitory gains in terms of benefit cost ratio (B: C ratio) were also achieved in T_4 and T_5 treatments. Inclusion of green manuring (GM) particularly Sesbania and Crotolaria along with Gypsum use resulted in to markedly reduction in pH, EC and BD and improvements in organic carbon, available NPK and micronutrients in sodic soils in Tonk district of Rajasthan. Study further revealed that introduction of green manuring in Kharif fallow fields reserved for mustard sowing in Rabi season got fitted in prevailing cropping system.

Table 3: Effect of gypsum and green manuring on mustard yield at farmer’s field (2011-2014)

<table>
<thead>
<tr>
<th>OFT Treatment Details</th>
<th>Mustard yield (Qha⁻¹)</th>
<th>2011-12</th>
<th>2012-13</th>
<th>2013-14</th>
<th>Pool Data</th>
<th>B:C Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>T_1: Farmer’s practice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>16.97</td>
<td>17.33</td>
<td>17.73</td>
<td>17.30</td>
<td>2.20</td>
</tr>
<tr>
<td>T_2: Gypsum (50% of GR) + FYM+ RDF</td>
<td></td>
<td>20.64</td>
<td>21.93</td>
<td>22.77</td>
<td>21.32</td>
<td>2.55</td>
</tr>
<tr>
<td>T_3: Gypsum (50% of GR) + Green Manure (Green gram)+ RDF</td>
<td></td>
<td>22.51</td>
<td>23.67</td>
<td>24.00</td>
<td>23.39</td>
<td>2.89</td>
</tr>
</tbody>
</table>
Table 2: Effect of gypsum and green manuring on mustard yield attributes at farmer’s field (2011-2014)

<table>
<thead>
<tr>
<th>OFT Treatment Details</th>
<th>Plant height (cm)</th>
<th>No. of Seliqua/plant</th>
<th>No. of seeds / Seliqua</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁: Farmer’s practice</td>
<td>168</td>
<td>161</td>
<td>161</td>
</tr>
<tr>
<td>T₂: Gypsum (50% of GR) + FYM+RDF</td>
<td>172</td>
<td>164</td>
<td>163</td>
</tr>
<tr>
<td>T₃: Gypsum (50% of GR) + Green Manure (Green gram)+ RDF</td>
<td>174</td>
<td>167</td>
<td>167</td>
</tr>
<tr>
<td>T₄: Gypsum (50% of GR) + Green Manure (Sesbania)+RDF</td>
<td>176</td>
<td>168</td>
<td>170</td>
</tr>
<tr>
<td>T₅: Gypsum (50% of GR) + Green Manure (Crotolaria)+ RDF</td>
<td>179</td>
<td>171</td>
<td>173</td>
</tr>
<tr>
<td>CD at 5 %</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

Table 4: Effect of gypsum- green manure on basic soil properties after harvest at farmer’s field (2013-14)

<table>
<thead>
<tr>
<th>OFT Treatment Details</th>
<th>Basic soil characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pH</td>
</tr>
<tr>
<td>T₁: Farmer’s practice</td>
<td>8.7</td>
</tr>
<tr>
<td>T₂: Gypsum (50% of GR) + FYM+RDF</td>
<td>8.5</td>
</tr>
<tr>
<td>T₃: Gypsum (50% of GR) + Green Manure (Green gram)+ RDF</td>
<td>8.4</td>
</tr>
<tr>
<td>T₄: Gypsum (50% of GR) + Green Manure (Sesbania)+RDF</td>
<td>8.7</td>
</tr>
<tr>
<td>T₅: Gypsum (50% of GR) + Green Manure (Crotolaria)+ RDF</td>
<td>8.6</td>
</tr>
</tbody>
</table>
Table 5: Effect of gypsum-green manure on available nutrient in soil after harvest of mustard at farmer’s field (2013-14)

<table>
<thead>
<tr>
<th>OFT Treatment Details</th>
<th>Available macro nutrient status (kg ha⁻¹)</th>
<th>2011-12</th>
<th>2013-14</th>
<th>2011-13</th>
<th>2013-14</th>
<th>2011-12</th>
<th>2013-14</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁: Farmer’s practice</td>
<td></td>
<td>230</td>
<td>235</td>
<td>11</td>
<td>13</td>
<td>182</td>
<td>185</td>
</tr>
<tr>
<td>T₂: Gypsum (50% of GR) + FYM</td>
<td></td>
<td>245</td>
<td>260</td>
<td>13</td>
<td>15</td>
<td>198</td>
<td>200</td>
</tr>
<tr>
<td>T₃: Gypsum (50% of GR) + Green Manure (Green gram)</td>
<td></td>
<td>240</td>
<td>265</td>
<td>12</td>
<td>16</td>
<td>195</td>
<td>200</td>
</tr>
<tr>
<td>T₄: Gypsum (50% of GR) + Green Manure (Sesbania)</td>
<td></td>
<td>235</td>
<td>290</td>
<td>13</td>
<td>22</td>
<td>195</td>
<td>210</td>
</tr>
<tr>
<td>T₅: Gypsum (50% of GR) + Green Manure (Crotolaria)</td>
<td></td>
<td>230</td>
<td>280</td>
<td>11</td>
<td>20</td>
<td>189</td>
<td>205</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OFT Treatment Details</th>
<th>Available micro nutrient status (mg kg⁻¹)</th>
<th>2011-12</th>
<th>2013-14</th>
<th>2011-13</th>
<th>2013-14</th>
<th>2011-12</th>
<th>2013-14</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁: Farmer’s practice</td>
<td></td>
<td>22</td>
<td>23</td>
<td>4</td>
<td>5</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>T₂: Gypsum (50% of GR) + FYM</td>
<td></td>
<td>21</td>
<td>25</td>
<td>3</td>
<td>6</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>T₃: Gypsum (50% of GR) + Green Manure (Green gram)</td>
<td></td>
<td>16</td>
<td>20</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>T₄: Gypsum (50% of GR) + Green Manure (Sesbania)</td>
<td></td>
<td>18</td>
<td>32</td>
<td>5</td>
<td>11</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>T₅: Gypsum (50% of GR) + Green Manure (Crotolaria)</td>
<td></td>
<td>15</td>
<td>25</td>
<td>4</td>
<td>9</td>
<td>11</td>
<td>17</td>
</tr>
</tbody>
</table>

Summary: Results of three years OFT have paved means and ways for improving sodic soil quality, input use efficiency and mustard productivity in salt affected areas at farmer’s field. The results further have confirmed that introduction of green manuring as technological interventions in addition to recommended package of practices for mustard crop could improve the sodic soil quality, input use efficiency and mustard productivity and may result in better utilization of sodic soil resource of country. The gap in nutrient removal and addition can be bridged only by practicing Integrated Nutrient Management. Crop production has to be increased accompanied with maintenance of soil health. To sustain the soil health in terms of fertility and productivity, supplementary and indigenous nutrient sources have to be explored and need to be recycled. Integrated Nutrient Management is based on three basic principles: assessment of soil fertility and climate, nature of crops not in isolation but as a part of cropping system and yield target and at least 30% of total nutrient levels of NPK to be in organic form.
Agroforestry based IFS: An approach for climate change mitigation and natural resource management

Puran Chandra and K.P. Mohapatra

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Agriculture has evolved about 10,000 to 12,000 years starting from primitive shifting cultivation and reached today's modern input driven intensive farming. Hunting, shifting cultivation and pastoral nomadism preceded settled agriculture. These activities are still prevalent in many developing countries. Shifting cultivation involves periodic shift to new land as the fertility of original patch is exhausted. It was practiced by our ancestor's 10-12 thousand years ago, but it is still source of food for millions of farmers from Asian, Africa and Latin America. It has been proven to be very successful adaption in difficult environmental conditions in tropics particularly when the rotation is kept 15-20 years. This is a natural way of utilizing vegetative means for replenishing soil fertility instead of costly chemicals and organic matter applied externally in more developed settled agriculture. Settled agriculture started with vegetative propagation of some crops like taro, cassava, sweet yams, sweet potatoes, arrow roots etc. this vegeculture was replaced about 3500 BC by seed agriculture based on wet rice cultivation where large ruminants were kept as drought animals. This framing system (crop-dominated) was widely prevalent in the most part of history. Most of the world was under this phase until 1850. The main cropping pattern was cereal based and animal were kept for draught purposed with almost no integration between subsystems. Two major trends between 1300 and 1800 AD led to the development of the mixed farming. These were the reduction and final elimination of fallow and pasture culture in rotation with crops which provided feed for livestock. Nitrogen fixing legumes were grown in mixed pastures where grasses helped to restore soil fertility. The importance of livestock gradually increased with the rise of income due to industrial revolution. This led to the development of integrated farming where livestock products became more important source of income to the farmers than crop produce. Grasses were grown with cereal and other crops. Livestock production was integrated with arable farming as livestock feed on crops/grasses grown on farm and manure from livestock help to maintain soil fertility.

Industrial revolution also had direct impact on agriculture. Crop husbandry became progressively intensive with the availability of better inputs like improved seeds, fertilizers and farm machinery. Farms became less mixed and many farmers now grow single products. With the degradation of land and soil health because of extensive use of exhaustive cropping led to the thinking of alternative systems that would help in improve the soil health and sustain the productivity of the land. Agroforestry system became more relevant in such situation which resembles more to the natural system where balance of the biological production system can be maintained. In NEH region, traditionally trees were deliberately integrated with the crop and livestock production.
system. A number crops like maize, ginger, pineapple, coffee, vegetables etc are grown with tree species such as *Pinus kesiya*, *Alnus nepalensis*, *Schima wallichii*, pear, plum, arecanut etc. The choice of a particular tree species and intercrop depends upon the climatic conditions of the area and economic importance of the species. NE region is rich in water resources and animal protein is deeply ingrained in the food habit of the local inhabitants. In this context, integrated farming systems become more sustainable, adaptable and acceptable in the socio cultural and ecological settings.

**Integrated faring systems:**

In integrated farming systems output from one subsystem become input for another system, which may otherwise be wasted. Here, different subsystems combine into whole and there is synergism in integrated faring since working together of the subsystem has a greater total effect then sum of their individual effects. Important features of integrated farming system are byproduct recycling, improved space utilization as of space, increase in the diversity of produce and decreased reliance on inter-farm or agro-industrial inputs making the system self sustainable. Integrated farming systems also reduce risk as less chemicals and pesticide are used and greater diversity of cropping system adopted. In integrated farming systems intensification is knowledge based rather than capital based and biological sources are used as input. Integrated farming involving aquaculture defined broadly is the concurrent or sequential linkage between two or more activities, of which at least one is aquaculture. These may occur directly on-site, or indirectly through off-site needs and opportunities, or both (Edwards, 1986; 1997). Benefits of integration are synergistic rather than additive; and the fish and livestock components may benefit to varying degrees. The term “waste” has not been omitted because of common usage but philosophically and practically it is better to consider wastes as “resources out of place” (FAO, 2003). Various components of IIFS are as follows.

1. **Soil health care:** Soil health is fundamental to sustainable intensification. Stem modulating legumes such as *Sesbania rostrata* and incorporating Azolla, blue green algae and to her sources of symbiotic and non-symbiotic nitrogen fixation are a part of the farming system. Vermiculture constitutes an essential component, green leaf manure and small quantities of powdered neem cake are used. These bulky organic supplements have to be generated on the farm itself to avoid transportation costs over long distances.

2. **Water harvesting and management:** Included in the agronomic practices are measures to conserve rain water so that it can be used in a conjunctive manner with other sources of water. Maximum emphasis is placed on on-farm water use efficiency and adopting drip and sprinkler irrigation of optimize the benefits from the available water. Efficiency, economy and equity in water use are to be ensured through cooperative management of catchment and command areas.

3. **Crop management:** Integrated nutrient supply is an important component. Plant nutrient can be supplied through different sources viz., organic manures, crop
residues, bio-fertilizers and chemical fertilizers. Integrated nutrient supply has to be chosen on the basis of farming system and the agro-ecological and soil conditions of the areas. Hybrids and high yielding varieties have to be cultivated. IIFS has to be based on both land saving agriculture and grain saving animal husbandry.

4. **Pest management:** Integrated pest management system forms a component. Antagonistic fungi such as *Trichoderma viride* and other beneficial bacteria like *Pseudomonas fluorescens* are used to control a host of pathogenic infection in a wide variety of crops. A wide range of botanical pesticides such as neem derivatives, extras of *Vitex nigundo*, custard apple seed oil. And a host of decoctions of local plants are used by farmers for either repelling or eliminating pests. The use of biological agents such as parasites and predators are used in place of toxic pesticides.

5. **Energy management:** Energy is an essential input. Every effort should be made to harness biogas, biomass, solar and wind energies to the maximum extent. Solar and wind energy is to be used in hybrid combinations with biogas for farm activities such as pumping water, drying grains and other farm produce.

6. **Post harvest management:** Best available threshing, storage and processing measures should be adopted. Value-added products from every part of the plant or animal have to be produced. Post-harvest technology assumes importance in the case of perishable commodities such as fruits, vegetables, milk, meat, eggs, fish and other animal products.

7. **Information, skill organization and management empowerment:** A meaningful and effective information and skill empowerment system is necessary for the success of the IIFS system. Decentralized production system will have to be supported by a few centralized key services such as supply of seeds, bio-pesticides, and diagnostic and control meteorological, management and marketing factors. Organization and management are key elements and depending on the area and farming system, steps have to be taken to provide small producers the benefits of scale in processing and marketing.

**Advantages of integrated farming systems**

Animal excreta provide nutrients for maintaining soil fertility and it can also be used for biogas and energy for household. Crop residues represent the other pillar on which the equilibrium of this system rests. They are fibrous by-products that result from the cultivation of cereals, pulses, oil plants, roots and tubers. They are a valuable, low-cost feed resource for animal production, and are consequently the major source of nutrients for livestock in developing countries. The overall benefits of crop-livestock integration can be summarized as follows (IFAD, 2009)

- Agronomic, through the retrieval and maintenance of the soil productive capacity;
- Economic, through product diversification and higher yields and quality at less cost;
• Ecological, through the reduction of crop pests (less pesticide use and better soil erosion control)

• Social, through the reduction of rural-urban migration and the creation of new job opportunities in rural areas

Types of integrated farming systems

Different farming systems as described by Devendra (1991) are rice fish system, integrated Pig-Duck-Fish-Vegetable system and integrated system involving animals. First two are traditional farming system practiced widely in south east asia with high rainfall.

Rice Fish farming system

Wild fish have been known to have entered flooded rice fields naturally, but situation subsided due to reduced stocks of wild fish, increase in fish diseases, toxic effects of chemical inputs and degeneration for water resources. In recent years, these circumstances have shifted increased attention to research on natural association between rice and fish with considerable success. The association of fish with rice offers several advantages.

• Reduce cost of cultivation through the removal of weeds, insects and pests that are consumed by fish

• Increased fertilization of the rice plants

• Provision of feed for fish, including the pollen from the rice flowers

• Increased productivity of the system (rice and fish)

Integrated Pig-Duck-Vegetable system:

The integrated system involving pig production, fish farming, duck keeping and vegetable production or a combination of these (Devendra and Fuller, 1979) is tradition and widely practiced in South East Asia and China. The interrelationship between the systems is based on the use of ponds which not only meets the needs of pigs but also enables fish and ducks rearing.

Integrated system involving various animals:

Unlike the tradition farming systems involving ponds and pigs-ducks-fish and vegetable that have been practiced for centuries and the inclusion of ruminants into these is relatively new. Ruminants, unlike pigs and ducks, are not normally reared concurrently with fish, adjacent to ponds and there are several reasons for this, for example extensive grazing habits or large ruminants, large amount of dung produced make it necessary to maintain animals in stall-fed conditions. Very limited research has been conducted in farming systems involving fish-crop and ruminants.
Intensive integrated farming systems:

Intensive integrated farming system (IIFS) is based on the concept that there is no waste and waste is only a misplaced resource which can become a valuable material for another product (Edward et al., 1986). It is a more refined and holistic approach of land use system through practices in which a number of production components are integrated Pig-Duck-Fish-Vegetable and integrated farming systems involving various animals. In IIFS all the components of agriculture like crop-fish-forestry-horticulture are integrated in a complementary way. The integral farming system so developed can provide the environmentally sustainable and economically viable technology.

IIFS systems have a good scope for North East Region particularly in high rainfall areas and livestock and fish can be main source of earning for the farmer. Keeping in view the scope and opportunities for NEH Region, IIFS models were developed and evaluated in ICAR RC for NEH Region, Umiam, Meghalaya. As a pilot project, about 10 ha of the waste land was taken up during the year 1999-2000. The average slope of the area ranged from 20-30 per cent with soil depth of <1m. The sloppy land was cleaned and contour bunds were prepared for gradual conversion of the slope to bench terraces at fixed vertical intervals of 3 m. Hedge row of Tephrosia candida, Flemingia macrophylla, Indegeofera tinctoria, Desmodium rensonii, Crotolaria tetragona and Cajanus cajan were raised on contour bunds for soil and water conservation and soil fertility build up. One year old seedlings of multipurpose tree species (Gmelina arborea, Alnus nepalensis, Chukrasia tabularis, Michelia champaca, Bauhinia variegata, Symingtonia populnea and Morus alba) and fruit trees (Psidium guajava, Citrus reticulata, C. lemon, C. sinensis, Pyrus communis, Prunus persica and Artocarpus heterophyllus) were planted during July 2000 at 5m x 5m spacing. The area at the lowest elevation of the farm (about 3.31 ha) was marshy where crop cultivation was not possible. Small water harvesting earthen ponds (07 nos) were created over 0.71 ha and 2.6 ha of marshy land were brought under cultivation of high value crops with assured irrigation facilities. Fish fingerlings was introduced in each ponds @ 6000 fingerlings/ha with species composition of catla (Catla catla)-20 per cent, rohu (Labeo rohita)- 10 percent, mrigal (Cirrhinus mrigala)- 20 percent, silver carp (Hypophthalmichthys molitrix)- 20 percent, grass carp (Ctenopharyngodon idella)-20 percent and goni (Labeo gonius)- 20 percent. Duck (Indian runner and Khaki Campbell), pig (large black), layer birds (White leghorn), goat (Black Bengal) and cow (Holstein breed) were reared and integrated with fishery. One pond was kept as control to compare the fish growth without integration of livestock/poultry/ducks. Vermicompost, liquid manure and mushroom cultivation was started in IIFS. The five subsystems of IIFS was developed as detailed in table 1 (Bhatt, and Bujarbaruah, 2005).
Table 1. Description of Intensive Integrated Farming System models

<table>
<thead>
<tr>
<th>Farming system</th>
<th>Landuse component</th>
<th>Area (ha)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Broiler chicken-Crop-Fish-Duck-Horticulture-Nitrogen fixing hedge row</strong></td>
<td>Pond-0.15, Pond dyke-0.03, Duck shed-0.016, Broiler shed-0.006, Field crop-0.75</td>
<td>1.06</td>
<td>In upland area, ragi (0.18 ha), maize (0.30 ha) and rice bean (0.12 ha) followed by ginger and turmeric. In lowland area: Paddy (0.65 ha) and mustard 0.30 ha were cultivated. During rabi season potato, tomato, cabbage, knol khol and radish were cultivated. Nitrogen fixing shrubs were planted on contour bunds, fodder grasses and fruit trees were raised on pond dykes and farm boundaries. Ducks were reared (72 Nos) on pond dykes. Composite fish culture was practiced and 900 fingerlings were stocked.</td>
</tr>
<tr>
<td><strong>Crop-Fish-Poultry-Multipurpose trees</strong></td>
<td>Pond-0.12, Pond dyke-0.04, Poultry shed-0.01, Field crop-0.80</td>
<td>0.97</td>
<td>In upland area, Paddy (0.45 ha) and rice bean (0.05 ha) during kharif and buckwheat (0.50 ha) in rabi season was cultivated. In lowland area: Paddy (0.30 ha) in Kharif and potato (0.25 ha) and french bean (0.05 ha) were cultivated. Fodder grasses and fruit trees were raised on pond dyke and farm boundaries. Layer bird (52 Nos.) were raised on pond dykes. Composite fish culture was practiced and 720 fingerlings were stocked.</td>
</tr>
<tr>
<td><strong>Crop-Fish-Goat-MPTs-Hedge</strong></td>
<td>Pond-0.10, Pond dyke-0.035, Goat shed-0.008, Field crop-0.80, Hedge row-0.10</td>
<td>1.04</td>
<td>In upland area, Paddy (0.30 ha), ginger (0.30 ha), turmeric (0.20 ha) during kharif and mustard (0.30), tomato (0.40 ha) and radish (0.10 ha) during rabi season were grown. Fodder grasses, MPTs and fruit trees were cultivated on pond dike and farm boundary. Goats (6 nos) were reared on pond dyke. Composite fish culture was practiced and 600 fingerlings were stocked.</td>
</tr>
<tr>
<td><strong>Crop-Fish-Pig-Bamboo-MPTs-Fruit trees-Hedge rows</strong></td>
<td>Pond-0.12, Pond dyke-0.035, Pig shed-0.001, Field crop-0.80, Hedge row-0.09</td>
<td>1.05</td>
<td>In upland area, Paddy (0.30 ha), colocasia (0.10 ga) and maize (0.40 ha) during kharif and brinjal (0.10 ha), radish (0.05 ha), potato (0.30 ha) and buck wheat (0.15 ha) during rabi season were cultivated. MPTs and fruit trees were raised on pond dykes and farm boundaries. Edible bamboo species were also cultivated on farm boundary. Hedge row rows were planted on contour bunds. Vermicompost was prepared in two units each of 12’ x 6’ x 2’ size. Pigs (2 Nos) on pond dykes. Composite fish culture was practiced and 720 fingerlings were stocked.</td>
</tr>
<tr>
<td><strong>Crop-Fish-Dairy-MPTs-Fruit trees-Hedge rows- Vermiculture-Liquid manure-Broom</strong></td>
<td>Pond-0.12, Pond dyke-0.06, Dairy shed-0.016, Field crop-0.80, Hedge row-0.17</td>
<td>1.17</td>
<td>In upland area paddy (0.60 ha) was cultivated. Broom grass (0.10 ha) and job’s tear (0.10 ha) were cultivated along the water channels. MPTs and fruit trees with fodder grasses were raised on pond dyke and farm boundary. Cattle (2 milch cows and 2 calves) was reared. Oyster mushroom was cultivated in 8 m x 3 m x 2.5 m size unit. Liquid manure was prepared in 3 units 3’x 3’x 2.5’ capacity. Vermi-composting was done in 6 units of 1 m x 1 m x 0.75 m. Composite fish culture was practiced and 720 fingerlings were stocked.</td>
</tr>
</tbody>
</table>
Upland crops, and fish farming without integration (control) | Pond-0.10 | Pond dyke-0.05 | Crop area-0.80 | 0.95 | Practiced in the ponds. Composite fish culture was practiced and 720 fingerlings were stocked.

In upland area, paddy (0.40 ha) and maize (0.40 ha) during kharif season and buck wheat (0.20 ha) and French bean (0.30 ha) were grown. Fruit trees were grown on pond dyke. Composite fish culture was practiced and 600 fingerlings were stocked.

Source: Bhatt and Bujarbaruah, 2005

The monetary input and output has also been calculated for each subsystem. The total output/input ratio was highest (1.76) in Crop-Fish-Dairy-MPTs-Fruit trees-Hedge rows-Vermiculture-Liquid manure-Broom followed by Broiler chicken-Crop-Fish-Duck-Horticulture-Nitrogen fixing hedge row (1.58) (Table-2). The monetary output/input could further increase if family labour is engaged for adopting IIFS (For detail report, refer to Bhatt and Bujarbaruah, 2005).

**Table 2: Monetary output/input pattern (Rs/yr) of intensive integrated farming systems**

<table>
<thead>
<tr>
<th>Farming system</th>
<th>Total input (Rs)</th>
<th>Total output (Rs)</th>
<th>Output/input ratio (Including labour component)</th>
<th>Output/input ratio (excluding labour component)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broiler chicken-Crop-Fish-Duck-Horticulture-Nitrogen fixing hedge row</td>
<td>1,05,722</td>
<td>1,67,331</td>
<td>1.58</td>
<td>2.24</td>
</tr>
<tr>
<td>Crop-Fish-Poultry-Multipurpose trees</td>
<td>60,137</td>
<td>90,625</td>
<td>1.51</td>
<td>2.12</td>
</tr>
<tr>
<td>Crop-Fish-Goat-MPTs-Hedge</td>
<td>59,442</td>
<td>91,880</td>
<td>1.55</td>
<td>2.40</td>
</tr>
<tr>
<td>Crop-Fish-Pig-Bamboo-MPTs-Fruit trees-Hedge rows</td>
<td>77,273</td>
<td>1,09,887</td>
<td>1.42</td>
<td>1.86</td>
</tr>
<tr>
<td>Crop-Fish-Dairy-MPTs-Fruit trees-Hedge rows-Vermiculture-Liquid manure-Broom</td>
<td>1,70,120</td>
<td>2,98,735</td>
<td>1.76</td>
<td>2.48</td>
</tr>
<tr>
<td>Upland crops, and fish farming without integration (control)</td>
<td>31,773</td>
<td>34,894</td>
<td>1.09</td>
<td>1.50</td>
</tr>
</tbody>
</table>

Source: Bhatt and Bujarbaruah, 2005

To establish these small water harvesting structures of 0.10 to 0.15 h, average cost involved in the first year was Rs. 43,200/- per pond. The average capacity of water retention ranged from 1000 to 1800 cubic meter and average cost of one cubic meter
Water harvesting was estimated to be Rs. 32.36. It indicated that one liter of water could be harvested/conserved at price of Rs. 0.03 in first year itself which includes the cost of excavation, ramming, slope stabilization, plantation cost of planting Congo and guinea grass, spillway making etc. Second year onward there was no cost involved except the maintenance cost whereas water could be harvested regularly. The details of water used for various purposes have been shown in table 3.

Table 3: Water harvesting and utilization pattern in Intensive Integrated Farming Systems

<table>
<thead>
<tr>
<th>IIFS</th>
<th>Water harvested in pond (m³)</th>
<th>Water utilization (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>System-1</td>
<td>1000</td>
<td>Fishery - 924</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vegetables - 70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fruit trees - 5.3</td>
</tr>
<tr>
<td>System-2</td>
<td>1800</td>
<td>Fishery - 1675</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vegetables - 83</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Duckery - 37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MPTs - 4.5</td>
</tr>
<tr>
<td>System-3</td>
<td>1200</td>
<td>Fishery - 1003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vegetables - 67.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Poultry - 126</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MPTs - 3.2</td>
</tr>
<tr>
<td>System-4</td>
<td>1300</td>
<td>Fishery - 1170</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vegetables - 89.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Goat - 36.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MPTs - 4.5</td>
</tr>
<tr>
<td>System-5</td>
<td>1320</td>
<td>Fishery - 1123</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vegetables - 76.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pig - 54.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fruit trees - 3.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vermiculture - 63.1</td>
</tr>
</tbody>
</table>

Source: Bhatt and Bajarbaruah, 2005

In integrated farming systems biological sources produced in-situ by one subsystem are used as input for another subsystem. Few studies indicate that suitable integration between different components of any system can increase the overall growth of the system by 30-40 per cent. Various forms of the integration like rice-fish integration, integrated pig-duck-fish-vegetable system, integrated system involving various animals and fish are very popular in high rainfall areas. Integrated farming system are very useful for increasing farm income of poor farmers of North East India.
References


Options of vegetable base farming system in era of climate change

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Climate change is both a global and a local phenomenon; anything affecting the ability to produce food in any of these regions is a threat to our food supply and the overall sustainability of our food system. The climate has always been changing and species and ecosystem have responded to these changes and adapted at rapid rate to the changed climate. The developing countries are most affected from the negative consequences of global warming although they have contributed relatively little to the cause of global warming.

The drier and warmer weather will ultimately result in shorter growing season and lesser crop yields which will adversely influence the livelihood of millions of people. The climate change is seriously affecting and altering the distribution, quality of natural resources and the associated livelihoods of the people. The demand for drinking water and for irrigation is increasing due to this change in climate increasing competition and conflict between the rural, urban and the industrial users. This may lead to sustainability crises for requirement of food, fodder and fuel-wood. On the other hand assessing crop quality is particularly important for speciality crops where quality is determined in large part by the presence and concentrations of specific phytonutrients and secondary metabolites that benefit consumers (Ahmed et al., 2014). Vegetables are the best resource for overcoming micronutrient deficiencies and provide smallholder farmers with much higher income and more jobs per hectare than staple crops (AVRDC 2006). Some secondary metabolites also serve as signal compounds to attract pollinating and seed-dispersing animals (Wink, 2015). Myer et al. (2014) demonstrated that increasing carbon dioxide concentrations resulted in decreased concentrations of zinc and iron in C3 grains and legumes with implications for human nutrition. Climate variables may also influence antioxidant activity of speciality crops (Mattos et al., 2014). Vegetables are generally sensitive to environmental extremes, and thus high temperatures and limited soil moisture are the major causes of low yields in the tropics and will be further magnified by climate change.

Plants may respond similarly to avoid one or more stresses through morphological or biochemical mechanisms (Capiati et al. 2006). Environmental interactions may make the stress response of plants more complex or influence the degree of impact of climate change. Measures to adapt to these climate change-induced stresses are critical for sustainable tropical vegetable production. Extreme climatic conditions will also negatively impact soil fertility and increase soil erosion. Thus, additional fertilizer application or improved nutrient-use efficiency of crops will be needed to maintain productivity or harness the potential for enhanced crop growth due to increased atmospheric CO2. Climatic changes will influence the severity of environmental stress...
imposed on vegetable crops. Moreover, increasing temperatures, reduced irrigation water availability, flooding, and salinity will be major limiting factors in sustaining and increasing vegetable productivity.

**Environmental constraints limiting vegetable production**

Increased global temperatures and carbon dioxide levels over the past six decades, coupled with greater weather variability and more extreme weather conditions such as droughts and floods, are impacting crop yields and shifting the geographical ranges of crop cultivation (Ewert et al., 2005). At the same time, while agriculture is vulnerable to climate dynamics, it is also a major driver of global environmental change, contributing to more than 25% of global greenhouse gas emissions (Edenhofer et al., 2014). Extreme climatic conditions will also negatively impact soil fertility and increase soil erosion.

**Temperature**

Temperature is recognized as the most significant factor affecting antioxidant activity in vegetables and fruits (Mattos et al., 2014). And increased temperatures have been shown to generally reduce vitamin content in fruit and vegetable crops (McKeown et al., 2006). In tomato, high day temperatures (more than 30 °C) and night temperature (above 21 °C) can cause significant losses in productivity due to reduced fruit set, smaller size and low-quality fruits. Pre-anthesis temperature stress is associated with developmental changes in the anthers; particularly irregularities in the epidermis and endothelium; lack of opening of stromium and poor pollen formation (Sato et al., 2002). The pre-anthesis stage is more sensitive in tomato. Post-pollination exposure to high temperature inhibits fruit set in pepper, indicating sensitivity of fertilization process (Erickson and Markhart 2002). Several connecting reasons for fruit drop has been enumerated (Hazra et al., 2007) such as bud drop, abnormal flower development, poor pollen development, dehiscence and viability, ovule abortion and poor viability and other reproductive abnormalities.

In cucumber, sex expression is affected by temperature. Low temperatures favours female flower production, which is desirable and high temperatures lead to production of more male flowers (Wien 1997). The duration of onion gets shortened due to high temperature leading to reduced yields (Daymond et al., 1997). In onion temperature increase above 40 °C reduced the bulb size and increase of about 3.5 °C above 38 °C reduced yield (Lawande et al., 2010). Cauliflower performs well in the temperature range of 15-25 °C with high humidity. Though some varieties have adapted to temperatures over 30 °C, most varieties are sensitive to higher temperatures and delayed curd initiation is observed (Singh 2010). In potato, reduction in marketable grade tuber yield to the extent of 10-20% is observed due to high temperature and frost damage reduced tuber yield by 10-50%, depending upon intensity and stage of occurrence.
Carbon dioxide concentration

The horticultural crops having C3 photosynthetic metabolism have shown beneficial effects indicated the increase in onion yield by 25-30% mainly due to increases in bulb size at 530 ppm CO₂ (Wurr et al., 1998). Tomato also showed 24% higher yield at 550 ppm CO₂ due to increase in a number of fruits (Srinivas Rao et al., 2010). Tomatoes grown with CO₂ enrichment exhibited a non-epinastic foliar deformation similar to nutrient deficiency symptoms. Hogy and Fangmeier (2009) studied the effect of high CO₂ concentration on the physical and chemical quality of potato tuber. They observed that increase in atmospheric CO₂ (50 % higher) increase tuber malformation in approximately 65% result in poor processing quality and a trend towards lower tuber greening around 12 %. Higher CO₂ level (550 µmol CO₂ mol⁻¹) increase the occurrence of common scab by 134 %.

Flood

Most vegetables are sensitive to excess moisture stress conditions due to reduction in oxygen in the root zone. Tomato plants under flooding conditions accumulate endogenous ethylene, leading to rapid epinastic leaf response. Onion is also sensitive to flooding during bulb development with yield loss up to 30-40%. Excessive rains/moisture or flooding also causes stress to the annual crops particularly vegetable crops. In case of tomato flood situation has been reported to cause accumulation of endogenous ethylene which may cause damage to the plants. The severity of flooding symptoms such as wilting and death of tomato plants increases with high temperature (Kuo et al., 1982). Soil water stress at early stages of onion crop growth caused 26% yield loss. In tomato, water stress accompanied by temperature above 28 °C induced about 30-45% flower drop in different cultivars (Srinivasa Rao 1995).

Drought

Drought stress reduces leaf size, stems extension and root proliferation, disturbs plant water relations and reduces water-use efficiency. Plants display a variety of physiological and biochemical responses at cellular and whole organism levels towards prevailing drought stress, thus making it a complex phenomenon. CO₂ assimilation by leaves is reduced mainly by stomata closure, membrane damage and disturbed activity of various enzymes, especially those of CO₂ fixation and adenosine triphosphate synthesis. Injury caused by reactive oxygen species to biological macromolecules under drought stress is among the major deterrents to growth. Although plants display a range of mechanisms to withstand drought stress. Chilli also suffers drought stress, leading to yield loss up to 50-60%. In potato, early season drought stress significantly minimized the water-use efficiency, leading to greatly decreased growth and biomass accumulation (Costa et al., 1997).
Salinity

Vegetable production is threatened by increasing soil salinity particularly in irrigated croplands which provide 40% of the world’s food (FAO 2001). According to the United States Department of Agriculture (USDA), onions are sensitive to saline soils, while cucumbers, eggplants, peppers, and tomatoes, are moderately sensitive (The World Vegetable Center). Physiologically, salinity imposes an initial water deficit that results from the relatively high solute concentrations in the soil, causes ion-specific stresses resulting from altered K+/Na+ ratios, and leads to a build-up in Na+ and Cl- concentrations that are detrimental to plants (Yamaguchi & Blumwald 2005).

Management for stress

Vegetable germplasm with tolerance to drought, high temperatures and other environmental stresses, and ability to maintain yield in marginal soil must be identified to serve as the source of the traits for both public and private vegetable breeding programmes. This germplasm include both cultivated and wild accessions possessing genetic variation unavailable in current widely grown cultivars. Genetic populations are being developed to introgress and identify genes conferring tolerance to stresses and at the same time generate tools for gene isolation, characterization, and genetic engineering. Furthermore, agronomic practices that conserve water and protect vegetable crops from sub-optimal environmental conditions must be continuously enhanced and made easily accessible to farmers in the developing world. Therefore it is also very essential to develop new strains/varieties of food crops which could counteract the adverse effects of heat, drought, growing period, erratic rainfall pattern etc. Programmes for efficient utilization of water and soil resources, in addition, to minimize greenhouse gas emission should be conducted. One such management strategy is to modify the plant’s root system to identify a suitable plant type or enhance or improve the tolerance to abiotic stresses in fruit and vegetable crops through grafting (Bhatt et al 2014). Artificial induction of drought resistance through exogenous use of various growth regulating and other chemicals has proven worthwhile in producing drought resistance at various growth stages in a number of plants.

Conclusion

Global environmental change and food security are among two of the most pressing societal issue today. The climate change parameters such as temperature, rainfall pattern and humidity have direct impact on diseases and insect pest infestations ultimately foremost in the dropping of production, productivity and quality of horticultural product. Identification of germplasm which is resistance/tolerance to biotic and abiotic stress is also of the important method to manage the climate change. A systemic approach, where all available options are considered in an integrated manner, will be the most effective and ultimately the most sustainable, particularly for developing countries under a variable climate.
Reference


Opportunities and strategies for maize based fodder production for sustainable integrated farming system in North-East India

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Introduction

North-Eastern region (NER) of India, which is popularly known as “Seven Sisters” encompasses Arunachal Pradesh, Assam, Meghalaya, Manipur, Mizoram, Nagaland, Sikkim and Tripura which occupies approximately 7.8 per cent of the country’s total land area and supports about 3.73 per cent of the country’s population (Ram et al., 2012). Agriculture is the main source of livelihood for majority of rural population in this region which is dominated by smallholders adopting low input-low output and technologically lagged mixed farming system. Livestock is a vital component of mixed farming system of NER as native people prefer meat in their diet which is socially as well as religious approved in this region. In addition to traditional meat-consuming habit, several factors like urbanization, change in life-style and increasing per capita income create a huge demand for livestock products (Kumar et al., 2007). Milk and milk products are, however, consumed in much lower quantity in this part when compared to Northern states of India due to low milk availability and high meat consumption. But recently the demand of milk and milk products is also growing up due to increasing per capita income and changes in life style. However, meeting the burgeoning demand for livestock and dairy products in these states will be an up-hill task. One of the main reasons for low production of livestock sector is substantial gap between the demand and availability of feed and fodder in NER. In order to fully harness the genetic potential of high yielding animals, good quality fodder in sufficient quantity should be fed to them. So, adequate supply of highly nutritious feed and fodder is indispensable for boosting livestock production.

Integration of livestock rearing along with crop cultivation, especially fodder, is compatible and economical. Rearing livestock is also an important means of income generation for people living in drought-prone, hilly, tribal and other less favoured areas where crop production may not be certain. As crop residues is a major part of animal feed, the integration of livestock rearing in farming systems is common. It is obligatory to generate interest among farmers towards livestock farming in NER, at the same time growing enough fodder to make it available round the year for livestock animals. In NER, maize is used both for direct consumption and as well as feed for piggery and poultry farming. A versatile crop like maize which can be used for fodder and feed purpose can be integrated with livestock rearing in farming systems of NER. As a fodder crop, maize is quick growing, high yielding and provides palatable and nutritious forage which can be fed at any stage of growth without any risk to animals. Maize fodder can be fed as green
or dry and makes excellent silage. Also, maize grain is used as a concentrate feed for both poultry and milch animals.

**Opportunities and strategies for maize based fodder production in farming system**

Cultivation of grain maize is popular especially in rainfed upland hill slopes of NER, however, its yield is very low due to cultivation of low yielding local varieties under both moisture and soil fertility stresses (Choudhary et al., 2013). The cultivation of quality grass/fodder is rare and the quantity is inadequate. For poor farmers of NER with small land holdings, cultivation of food crops is on first priority and the cultivation of fodder gets lower priority. So, it may not be possible for them to devote extra land for fodder cultivation due to ever increasing pressure on arable land from grain and commercial crops. In this context, the only option to meet the fodder requirement is to enhance the production of fodder per unit area per unit time. This can be achieved by intercropping of high yielding varieties and hybrids of maize with crops like soybean, groundnut, rice bean, ginger, turmeric, potato, sweet potato etc. This will ensure both food and fodder security for the farmers of this region.

Remunerative crops such as speciality maize (like baby corn and sweet corn) have the potential to penetrate and fit into farming systems of NER. Harvesting of maize at baby corn or at green cob stage maize makes an ideal fodder with highly palatability for livestock animals (Shanti et al., 2012). Baby corn fodder which is green stalks with leaves left after harvest of baby corn, is estimated to yield about 30 tonnes/ha (Bakshi et al., 2016). Also, baby corn husk along with silk (6.4–7.4 tonnes/ha), is highly nutritious which can be fed to ruminants (Bakshi and Wadhwa 2012). These stalks of baby corn and sweet corn are reported to be comparable with fodder maize in regard to nutritional quality (Bakshi et al. (2017). At present, baby corn and sweet corn are gaining popularity among general mass in the country especially effluent and upper middle class and they are being sold at premium prices in markets. So, farmers of this region can generate good income as well as highly nutritious fodder for livestock by cultivating these speciality corns. Certain short duration varieties for baby corn purpose namely DHM 109, HM-4, Hybrid maize 5, HIM 129, MTH-14, RCM 1-1, RCM 1-3, Prakash, Pusa Extra Early Hybrid maize 5, Vivek Maize Hybrid 23, Vivek Maize Hybrid 25 and VL Makka 42 have been identified suitable for cultivation in NER. Also, intercropping of short duration varieties of crops like potato, garden pea, coriander, broccoli, turnip etc. can be followed with baby corn (Ansari et al., 2015).

**Conclusion**

Maize holds a strong potential to fit well in prevailing farming system of NER and enhance fodder production to meet nutritional requirement of their livestock animals. However, to reap all these benefits by farmers of NER, it is important to ensure availability of good quality seed of high yielding varieties and hybrids suitable for this particular region. Also, proper fertilizer and manure application and adoption of proper
package of practices are mandatory for achieving higher production of maize. To promote cultivation of speciality maize, it is essential to provide better access to processing and marketing facility in rural areas.

References


Eco-friendly Management of Major Pests of Horticultural Crops in northeast India

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Introduction

Agro-climatic conditions are quite conducive for fruits and vegetable cultivation in northeast India and more than 20 vegetables belonging to cruciferous (cole crops), solanaceous, cucurbitaceous, leguminous, tuber crops and leafy vegetables are grown in the region. Vegetables like cabbage, cauliflower, radish, brinjal, tomato, okra, chillies, pumpkin, bottle gourd, cucumber, radish, carrot, spinach, beans and cowpea are commonly grown in jhum and low land. Among fruits, citrus, temperate fruits and guava are the important crops grown in the region.

Pest of vegetable crops

Cruciferous crops

Cole crops are extensively grown throughout the year. Cole crops viz., cabbage, cauliflower, radish, knol-khol and gobhi sarson are attacked by a large number of insect pests like cabbage butterfly, aphids, diamond back moth, cabbage head borer, cabbage semilooper, cutworm, flea beetle, painted bug, leaf webber, cut worm and saw fly. Among these, cabbage butterfly and aphids are the most important pests.

Solanaceous crops

Brinjal

Insect pests are the major constraints in the production of brinjal throughout the region and pests responsible for quality and quantity deterioration are the fruit and shoot borer, jassid, aphids, white spotted flea beetle, leaf miner and whitefly. Infestation of these pests starts one week after transplanting. The population of jassids is generally high in the second week of August. Flea beetles are active and high in number in the first week of August to the second week of November.

Tomato

Cultivation of this crop is very limited and high rainfall does not permit its successful cultivation due to high incidence of pest and diseases. This crop is infested by fruit borer, aphid, cutworm, jassids and white fly, of which fruit borer is a major pest causing severe damage to the fruits thereby resulting in low yield.
Malvaceous

Okra

This crop is grown widely in the jhum as well as in low-lying areas of the region. Mostly indigenous tall varieties with fruits having prominent ridges are grown. Major insect pests of the crop are fruit and shoot borer. The blister beetle and oil beetle are found to damage okra severely and cause more than 40 per cent losses. Other pests infesting this crop are jassids, semi looper, leaf roller, bihar hairy caterpillar and fruit bugs.

Important pest of Vegetables: Diagnosis and Management

1. **Shoot & Fruit borer, *Leucinodes orbonalis* (Lepidoptera: Pyralidae)
   **Pest Diagnosis**

   The young caterpillars creamy white and full grown light pink, about 16 to 22 mm in length with a brownish head; moth is white with pale brown or black spots on the dorsum of the thorax and abdomen, wings are white with pinkish-red or bluish markings.

   **Nature of Damage**

   At early stage of plant growth, newly hatched larva bores through midrib and reaches the growing shoot, or directly enters into shoot at the angle of petiole with stem and feeds within growing tender shoot. As a result, midrib affected leaf dries and drop-off; in case of shoots, top portion with 4-5 leaves shows the typical withering and drooping symptom leading to drying of growing point. At later stage of growth of the plants, the caterpillar bores into flower buds and fruits, entering from under the calyx leaving no visible sign of infestation while the larvae feed inside. The damaged flower buds are shed without blossoming whereas the fruits may show circular exit holes.

   **Management**

   - IPM module consisting of mechanical destruction of infested shoots and fruits (fortnightly), pheromone traps (Leucilure) @ 100 traps/ha, single spray of Spinosad 0.02% and Novaluron 0.01% is very effective against brinjal fruit and shoot borer, *L. orbanalis*

2. **Cabbage butterfly, *Pieris brassicae nepalensis* (Lepidoptera, Pieridae)
   **Pest Diagnosis**

   Larvae, in its initial instars, pale yellow and turns greenish-yellow later on; fully grown larvae with black head, short hairs on body and dorsum with black spots. Adult butterfly creamy white with forewing apically black tipped two large black spots ventrally; female with dorsal black spot also; hind wing with large apical black spot.

   **Nature of Damage**

   The caterpillars alone cause damage. The first instar caterpillars just scrap the leaf surface, whereas the subsequent instars eat up leaves from the margins inwards, leaving
intact the main veins. Often, entire plants are eaten up. This is by far the most destructive pest on cabbage in NE India.

3. **Cutworm, *Agrotis ipsilon* (Lepidoptera, Noctuidae)**

   **Pest Diagnosis**

   Eggs are globular in shape, 0.5mm in diameter. Caterpillars are smooth, stout, cylindrical, 40 to 50mm long, blackish-brown dorsally and grayish-green laterally with dark stripes. They are greasy to touch. They coil up at the slightest touch. Pupae are 18 to 22mm long and reddish-brown in colour. Moths are medium-sized, stout, dark greenish-brown with reddish tinge and have grayish-brown wavy lines and spots on forewings; hind wings are hyaline having dark terminal fringe, which is darker in females than in males.

   **Nature of Damage**

   On hatching, the tiny caterpillars feed gregariously on foliage for a few days and then segregate and enter into the soil. The caterpillars are nocturnal in habit and hide during the day in cracks and crevices in the soil or under the clod or debris around the plants. At night they come out to feed, for which they cut the seedlings near ground level and eat only the tender parts; thus the loss caused is much more than what is actually eaten by these caterpillars.

4. **Cabbage aphid, *Brevicoryne brassicae* (Hemiptera, Aphididae) and Green peach aphid, *Myzus persicae***

   **Nature of Damage**

   Both the nymphs and adults suck the sap from the tender part of the plants. In cabbage the aphids enter the inner leaves of the head and in cauliflower all the inner space in the head is filled by the aphids, thus making the vegetable unmarketable. The aphids excrete honey dew on which sooty mould grows covering the dorsal surface.

5. **Leaf eating caterpillar, *Spodoptera litura* (Lepidoptera, Noctuidae)**

   **Pest Diagnosis**

   The forewings have beautiful golden and greyish brown patterns. The caterpillars are velvety black with yellowish-green dorsal stripes and lateral white bands.

   **Nature of Damage**

   The larvae feed on leaves and fresh growth. They are mostly active at night and cause extensive damage.

**Management:**

- Transplanting of cole crops in mid hills of Meghalaya should be completed during mid of the October, so as to have a very less infestation of cutworm, cabbage butterfly and cabbage aphid
- Collection and destruction of the grown up larvae of cutworm, as soon as infestation starts
• Two sprays of *Bacillus thuringiensis* @ 2ml/lit of water is very effective against 
cabbage butterflies and leaf eating caterpillars and it is also relatively safer to 
indigenous parasitoids e.g. *Hyposoter ebeninus*, *Cotesia glomerata* and 
*Trichogramma*

• Spray of Nimbecidine @ 2ml/lit of water along with yellow sticky traps @ 
1trap/100m² is effective against aphids

6. **Pea stem fly, Melanagromyza phaseoli (Diptera, Agromyziidae)**

**Pest Diagnosis**

Maggots are initially white in colour, later becoming yellowish, less than one mm in 
length. Adults are metallic-black flies, 2.0 to 2.5 mm long, having hyaline wings that have 
a distinct notch in the coastal regions.

**Nature of Damage**

The maggots burrow into the stem causing withering and ultimately drying of affected 
shoots, thus, reducing the bearing capacity of the host plant. Seedlings are more affected 
than grown up plants.

**Cultural Control**

• Early sowing of beans escapes blister beetle infestation during Kharif season.
• Removing dead plants and burning them to suppress the population of bean flies
• Two sprays of Nimbecidine @ 2ml/lit of water during seedling stage reduce stem fly 
damage

7. **Fruit borer, Helicoverpa armigera (Lepidoptera, Noctuidae)**

**Pest Diagnosis**

The eggs are yellowish-white, ribbed and dome-shaped, 0.4 to 0.5mm in diameter. 
Freshly hatched caterpillars are yellowish-white in colour and gradually acquire greenish 
tinge. Full grown caterpillars are 40 to 50 mm. Pupae are dark brown in colour, 11 to 
14mm long and have a sharp spine at the anal end. Moths are medium-sized, stout, 
ocreous with pale brown or reddish tinge; forewings are olive green to pale brown in 
colour with a dark circular spot in the centre and indistinct double waved antemedial 
lines; hind wings are pale smoky-white with a broad blackish outer border.

**Nature of Damage**

On hatching, the young caterpillars feed on tender foliage; advance stage caterpillars 
attack the fruits. They bore circular holes and thrust only a part of their body inside the 
fruit and eat the inner contents. The caterpillars are cannibalistic- freshly hatched ones 
may even feed on the eggs, while the older caterpillars prey on younger ones; sometimes 
these also attack caterpillars of other noctuid moths.
Management:
- Spraying of HaNPV @ 250LE/ha and release of *Trichogramma pretiosum* @ 50,000 parasitoids/ha OR spraying of 5% Neem Seed Kernel extract is very effective against fruit borers
- Spraying of *Bacillus thuringiensis* 8 SP @ 1.5 gm/lit during fruiting stage is also effective against tomato fruit borer

8. Blister beetle, *Mylabris pustulata* (Coleoptera, Meloidae)

**Pest Diagnosis**
Large beetles with black body, red elytra with white markings.

**Nature of Damage**
Adult beetles eat away the flowers completely; they also feed on tender fruits and growing buds.

**Management:**
- Application of entomopathogenic fungi *viz.*, *Beauvria bassiana* @ $1 \times 10^6$ cfu/ml effectively manage the blister beetles from August to October.

**Citrus**
Citrus is one of the major fruit crops of India, including NEH region. Northeastern region is endowed with citrus diversities and it is the natural home of citrus species like *Citrus indica*, *C. assamensis*, *C. latipes*, *C. ichangensis*, *C. macroptera*, *C. aurantium* and *C. medica*. Among mandarins Nagpur mandarin (Central India), Coorg mandarin (South India), Kinnon mandarin (Northwest India), Khasi mandarin (Northeast India), Sikkim mandarin (Sikkim) and Darjeeling mandarin (Darjeeling) are major commercial cultivars. The citrus production in this region has been suffering from various constraints. Every year, approximately 20% of the trees are dying in the region because of several factors and insects are one of them. The environmental conditions in this region are favourable for occurrence and build up of insect pests and natural enemies. The gradual decrease in production of Mandarin in the region is due to citrus decline and the incidence of insect pests and diseases.

Around 250 species of insects were reported in citrus ecosystem, out of these 42 are more common in this region. Among these, the trunk borer is the major pest of citrus in the region. Citrus psylla is the vector of citrus greening bacterium and the black aphid is the vector of citrus tristeza virus. Leaf miner is also equally important and damages the plant from the seedling stage during each new flush. The fruit sucking bug, *Rhynchocoris humeralis* is another serious pest and start sucking sap from fruits from the very beginning till harvest. In severe infestation, dropping of immature fruits is seen. Other pests of economic importance include lemon butterfly, leaf mining beetles, *Spodoptera* spp., leaf folder, looper, mealy bugs, scales, orange shoot borer, bark eating caterpillar, fruit sucking moths and fruit flies etc.
Major insect pests of citrus

1. **Citrus Trunk borer, *Anoplophora versteegi* (Coleoptera : Cerambycidae)**
   Citrus Trunk borer is one of the most destructive pests of citrus in entire NEH region. It accounts for 60-80 per cent damage to citrus orchards. Eggs are laid on trunks just above the soil level. Freshly hatched grubs feed beneath the bark and then bore inside the wood and tunnel through the pith taking a circuitous course. The infested plants and branches gradually dry up and the leaves wither away. Appearance of resinous exudation and saw-dust like powder on tree trunks indicate infestation.

2. **Citrus leaf miner, *Phyllocnistis citrella* (Lepidoptera : Phyllocnistidae)**
   The apodous larvae mine into the young and tender leaf tissues and form zigzag galleries. The larvae feed on the epidermal cells of the leaf leaving behind the remaining leaf tissues quite intact. The mine delves turn pale, get distorted and may dry up. Attack by this pest also encourages the development of citrus canker. The young nurseries are most severely affected. Attack on older plants, interferes with photosynthesis resulting in loss of vigour and considerable reduction in yield.

3. **Lemon butterfly, *Papilio demoleus* (Lepidoptera : Papilionidae)**
   The young larvae feed only on fresh leaves and terminal shoots. Habitually, they feed on margin inwards to the midrib. In later stages, they feed even on mature leaves and sometimes the entire plant may be defoliated. The pest is particularly devastating in nurseries and its damage to foliage seems to synchronize with fresh growth of citrus plants in April and August-September. Heavily attacked plants bear no fruits.

4. **Citrus psylla, *Diaphorina citri* (Hemiptera : Psyllidae)**
   Damage is caused both by nymphs and adults. On emerging, the nymphs have a tendency to stick close to the egg shell with the help of their sharp piercing mouthparts. They suck the cell sap. They are found congregated on young half open leaves but later on move to older leaves. As a result of feeding, the vitality of plants deteriorates and the young leaves and twigs stop growing further. The insect also injects certain toxins along with saliva, as a result the leaf buds, flower buds and leaves may wilt and die. Besides, bugs also excrete honey dew resulting in superficial black coating on the affected parts adversely affecting photosynthesis.

5. **Citrus black fly, *Aleurocanthus woglumi* (Hemiptera : Aleyrodidae)**
   The damage is done by both nymphs and adults by sucking the plant sap. Owing to the feeding, the plants remain stunted; curling of leaves takes place and also premature fall of flower buds and the developing fruits.

   The scales settle in large number on stem, branches, leaves and fruits and suck the sap. In the early stage, the plants lose their vigour and become stunted and gradually dry up. While feeding, they inject toxic substance into the plant sap resulting in yellow spots on leaves, twigs or fruits. In case of severe infestation, all the leaves turn pale.
Management of major pests of citrus

Cultural practices:

1. Deep ploughing of basin avoiding root cuts, to expose soil inhabiting/resting stages of insects, pathogen and nematodes.
2. Select deep, well levelled and good drainage soil.
3. Only certified seed should be used. Hot water treatment (51-52°C) of seeds for 10 minutes may be done.
4. Use resistant rootstocks and select disease free nursery plants.
5. Avoid flood and channel irrigation.
6. Avoid injuries to trunk and roots during farm operations.
7. Adopt proper spacing, irrigation and nutrient management.
8. Avoid application of high nitrogenous fertilizers.
9. Use neem cake @ one tonne/ha under assured moisture conditions in nematodes infected field only.
10. For the management of citrus white/black fly and mealy bug, intermingling branches should be pruned and spacing trees at closed distance should be avoided so that sunlight can reach through canopy from all the sides.
11. Fallen fruits should be destroyed by burning them to the ground. There should be clean cultivation of orchard to avoid further development of fruit sucking moths.
12. Remove cover crops early in the seasons, which effectively check the fruit sucking bugs, since the nymph are unable to move far away.
13. Ant colonies in the orchard should be destroyed as they are the carrier of mealy bugs to their feeding sites.
14. Following intercropping system is recommended to colonize the bioagent fauna such as lady bird beetles, lace wings etc.
   a. Citrus + cowpea
   b. Citrus + soybean

Mechanical practices:

1. Hand picking and removal of fallen leaves be ensured
2. Light traps may be operated for the management of citrus black fly, fruit fly and citrus butterfly.
3. Regular monitoring and killing of larva of borers and bark eating caterpillar by inserting wire inside the tunnel or insert cotton, swabbed with kerosene or petrol, in the hole and seal the hole with clay.
4. Polythene banding (1 feet wide) around the trunk during December-February to prevent bugs from climbing
Botanicals/ biopesticides:

1. Neem seed kernel extract (NSKE) 5 % are very effective in reducing sucking pest complex of citrus without effecting its natural enemies viz. lace wing flies etc.

2. Application of biopesticide viz. *Verticillium lecanni* @ 0.5 % twice at fortnightly interval during Feb.- March, June- July and Sept.- Oct. effectively reduces aphids, black flies, leaf miners, scales and psylla.

3. Application of *Paecilomyces fumosoroseus* culture @ 0.5 % twice at fortnightly interval at the time of leaf emergence reduces the mite population.

4. Application of *Beaveria bassiana* @ 0.5 % or *Bacillus thuringensis* @ 0.2 % thrice at fortnight interval during May- June checks the defoliators like lemon butterfly, *Spodoptera* spp., leaf folders and loopers etc.

5. Raking or ploughing the soil and application of *Beaveria bassiana* @ 5 kg/ha and *Metarrhizium anisopliae* @ 5 kg/ha to the soil underneath the tree canopy reduces mealy bugs and fruit flies respectively.

6. Application of neem + garlic spray @ 3.0 ml/l during rainy season act as a repellent for defoliators.

Chemical control measures:

1. Need based, judicious and safe application of pesticides are the most vital, triplicate segment of chemical control measures under the ambit of BIPM. It involves developing IPM skills to play safe with environment but proper health monitoring, observing ETLs and conserving biocontrol potential before deciding in favor of use of chemical pesticides as a last resort.

2. Poison baits for fruit flies and moths : Gur + Fruit juice 20 % + Malathion 2 % @ 40 baits/ha OR Methyl eugenol based fruit fly trap @15-20 traps/ha for trapping fruit flies

3. Following suggestions have important bearings for the success of control measures in the context of IPM strategy:
   - Minimize number of spray as many as possible and repeated application of same pesticides should be avoided
   - Avoid using of synthetic pyrethroids which results in resurgence of sucking pests and use selective insecticides if essential, during early phase of season
   - Use neem based formulation individually and
   - Proper spray equipment should be used
   - Knapsack sprayer is ideal for citrus garden and
   - use proper spray volumes for unit area 400-500 litre/ha.

Guava

Major pest of guava in the NEH region includes trunk borer, *Aristobia testudo* (Coleoptra: Cerambycidae); three species of fruit fly, *Bactrocera dorsalis*, *B. cucurbutae* and *B. tau* (Diptera, Tephritidae); two species of bark eating caterpillars, *Indarbela quadrimotata* and
I. tetraonis; Mealy scale, Chloropulvinaria psidii (Hemiptera, Coccidae), three species of mealy bugs Ferrisia virgata, Plannococcus citri, P. lilacinus (Hemiptera, Pseudococcidae), two species of tea mosquito bugs, Helopeltis antonii and H. theivora (Hemiptera: Miridae), aphids, jassids etc. Besides, Xylotrupes siamensis (Coleoptera: Scarabaeidae) was found to be a new pest in guava orchards. Details on diagnostic characters and biology of few important pests are discussed below;

1. Guava trunk borer, Aristobia testudo (Coleoptra, Cerambycidae)

Grub enters into stem at branching points and develops inside the trunk by making tunnel. As a result, the affected tree or branch starts withering and finally dry-up.

2. Guava fruit fly, Bactrocera dorsalis (Diptera, Tephritidae)

Females oviposit through the skin of fruits. The maggots feed inside the fruits making them unfit for marketing.

3. Guava mealy scale, Chloropulvinaria psidii (Hemiptera, Coccidae)

The scale insects are found in large numbers sticking to leaves on ventral side, tender twigs and shoots and cause leaf distortion and growth disturbance. The females feed voraciously and also exude copious quantity of honey dew on which sooty mould develops.

**Management practices**

Following pest management practices are suggested to reduce the guava pest problems in North east India

**Cultural practices:**

1. Deep ploughing of basin avoiding root cuts, to expose soil inhabiting/resting stages of insects, pathogen and nematodes.
2. Select deep, well levelled and well-drained soil.
3. Use resistant rootstocks and select disease free nursery plants.
4. Avoid flood and channel irrigation.
5. Avoid injuries to trunk and roots during farm operations.
6. Adopt proper spacing, irrigation and nutrient management.
7. Avoid application of high nitrogenous fertilizers.
8. Use neem cake @ 1 ton/ ha under assured moisture conditions in nematodes infected field only.
9. For the management of mealy bugs, intermingling branches should be pruned and spacing trees at closed distance should be avoided so that sunlight can reach through canopy from all the sides.
10. Fallen fruits should be destroyed by burning them to the ground. There should be clean cultivation of orchard to avoid further development of fruit flies.
11. Ant colonies in the orchard should be destroyed as they are the carrier of mealy bugs to their feeding sites.
Mechanical practices:

1. Hand picking and removal of fallen leaves be ensured
2. Light traps may be operated for the management of scarabid beetles.
3. Regular monitoring and killing of larva of trunk borer and bark eating caterpillar by inserting wire inside the tunnel or inserting cotton swabbed with kerosene or petrol, in the hole and sealing the hole with clay.

Biological control/Botanicals/ biopesticides:

1. Inundative release of the predator, *Chrysoperla* spp. (@ 2000/acre) and *Cryptolaemus montrouzieri* (@ 2-3 adults/tree) is quite successful in controlling mealy bugs
2. Neem oil (3 ml/litre) + Sweet flag 1% + release of *Mallada boninensis* @ 30 larvae/tree or one spray of imidacloprid 17.8 SL @ 0.05% + release of *Mallada boninensis* @ 30 larvae/tree is found very effective for controlling sucking pests.
3. Neem seed kernel extract (5 %) 5% are very effective in reducing sucking pest complex without affecting its natural enemies viz. lace wing flies etc.
4. Application of systemic biopesticide viz. *Verticillium lecanii* culture @ 0.5 % twice at fortnightly interval during Feb.- March, June- July and Sept.- Oct. effectively reduces aphids, scales and tea mosquito bugs.
5. Application of *Paecilomyces fumosoroseus* culture @ 0.5 % twice at fortnightly interval at the time of leaf emergence reduces the mite population.
6. Application of *Beaveria bassiana* @ 0.5 % or *Bacillus thuringensis* @ 0.1 % thrice at fortnightly interval during May- June checks the defoliators like *Spodoptera* spp., leaf folders and loopers etc.
7. Raking or ploughing the soil and application of *Beaveria bassiana* @ 5 kg/ha and *Metarrhizium anisopliae* @ 5 kg/ha to the soil underneath the tree canopy reduces mealy bugs and fruit flies, respectively.
8. Application of neem + garlic spray @ 3.0 ml/l during rainy season act as a repellent for defoliators.

Chemical control measures:

1. Need based, judicious and safe application of pesticides are the most vital, triplicate segment of chemical control measures under the ambit of BIPM. It involves developing IPM skills to play safe with environment but proper health monitoring, observing ETLs and conserving biocontrol potential before deciding in favor of use of chemical pesticides as the last resort.
2. Poison baits for fruit flies and moths : Gur + Fruit juice 20 % + Malathion 2 % @ 40 baits/ha
3. Use of RC-fruit fly traps @ 15-20 traps/ha during fruit development stage. Collect fallen fruits and destroy them.
4. Following suggestions have important bearing for the success of control measures in the context of IPM strategy:
• Minimize number of spray and repeated application of same pesticides should be avoided
• Avoid using of synthetic pyrethroids which results in resurgence of sucking pests and use selective insecticides (e.g. Karanjink) during early phase of season
• Proper spray equipment should be used; Knapsack sprayer is ideal for guava
• Garden and use proper spray volumes for unit area.
Strategies and management practices for stored grain pest

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ICAR Research Complex for NEH Region, Manipur Centre, Imphal - 795004

Wheat, rice, and maize belonging to the cereal grains or food grains constitute the most popular food crops in the world, and are the basis of staple food in most of the developing countries. Since 2010 onwards, India produces above 250 million tonnes of foodgrains annually. The year 2016-17 is also expected to be a bumper year with about 275 million tonnes as per Govt. data. Postharvest loss includes the food loss across the food supply chain from harvesting of crop until its consumption (Aulakh et al., 2013). Among postharvest operations, storage is responsible for the maximum loss (7.5%) while processing, threshing and transport cause 1%, 0.5% and 0.5% losses, respectively (Birewar, 1984). The losses can broadly be categorized as weight loss due to spoilage, quality loss, nutritional loss, seed viability loss, and commercial loss. “Food loss” is defined as food that is available for human consumption but goes unconsumed (Aulakh et al., 2013, Buzby et al., 2015).

The post-harvest losses in India amount to 12 to 16 million metric tons of food grains each year, an amount that the World Bank stipulates could feed one-third of India's poor. The monetary value of these losses amounts to more than Rs. 50,000 crores per year (Singh, 2010). Minimizing cereal losses in the supply chain could be one resource-efficient way that can help in strengthening food security, sustainably combating hunger, reducing the agricultural land needed for production, rural development, and improving farmers’ livelihoods.

Of all the biotic factors leading to qualitative and quantitative spoilage of food, arthropods are the most notorious and devastating. Stored product insects are adapted to infesting raw grains and cereal products, and are a constant threat to storage facilities worldwide. Among storage losses, pulses are most susceptible to damage due to insects (5%) compared to wheat (2.5%), paddy (2%) and maize (3.5%) (Deshpande and Singh, 2001).

In North Eastern region, maximum post-harvest loss was found to be 22.62 per cent for tomato followed by ginger, orange and pineapple. Except in tomato, the amount of loss was more in the market level when compared to the grower’s level. The post-harvest losses of these commodities were found to be very high and proper post-harvest management is the need of the hour.

Post-harvest insect pests may be primary, i.e. able to attack intact grains such as in the genus Sitophilus, while others are secondary pests, attacking already damaged grains or grain products such as those from the genus Tribolium (Parkin, 1956). Two major groups of insects harbour the most economically important post-harvest insect pests: Coleoptera (beetles) and Lepidoptera (moths).
Several Coleopteran and Lepidopteran species attack crops both in the field as well as the stored food. Crop damage by Lepidoptera is only done by its larvae. Several lepidopteran larvae entangle the feeding media through silky secretion, which turn products into entwined lumps (Trematerra and Pavan, 1995; Wang et al., 2004). In the case of Coleoptera, both larvae and adults often feed on the crop; and the two stages are responsible for the damages on various crops, including maize, wheat, sorghum, barley, and other cereals (Daglish et al., 1995).

Losses caused by insects can be both quantitative as well as qualitative. Insects feeds directly on the grain kernels causing loss in the weight of the stored grain. The losses vary depending on several factors such as moisture content in the grains, storage containers, storage period, grades and forms of grains, local climate conditions. Insect fragments and excrements contamination also leads to the loss of palatability and bad odour in stored grain. The extent of loss caused is also determined by moisture content and temperature. Insects are uricotelic organisms, thus uric acid produced by the insects, functions as a sensitive index of infestation of foodstuffs as well as the degree of insect population.

<table>
<thead>
<tr>
<th>Insect orders</th>
<th>Family</th>
<th>Species</th>
<th>Common name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coleoptera</td>
<td>Anobiidae</td>
<td>Lasioderma serricorne</td>
<td>Cigarette beetle</td>
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<tr>
<td></td>
<td></td>
<td>Stegobium paniceum</td>
<td>Drugstore beetle</td>
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<tr>
<td></td>
<td>Anthribidae</td>
<td>Araecerus fascicularis</td>
<td>Coffee bean weevil</td>
</tr>
<tr>
<td></td>
<td>Anthribidae</td>
<td>Prostephanus truncatus</td>
<td>Larger grain borer</td>
</tr>
<tr>
<td></td>
<td>Bostrichidae</td>
<td>Rhyzopertha dominica</td>
<td>Lesser grain borer</td>
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<td></td>
<td>Bruchidae</td>
<td>Acanthoscelides obtectus</td>
<td>Bean weevil</td>
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<td></td>
<td></td>
<td>Callosobruchus analis</td>
<td>Graham bean weevil</td>
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<tr>
<td></td>
<td></td>
<td>Callosobruchus chinensis</td>
<td>Azuki bean weevil</td>
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<td>Callosobruchus maculatus</td>
<td>Cowpea weevil</td>
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<td>Callosobruchus rhodesianus</td>
<td>Zabrotes subfasciatus</td>
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<td></td>
<td>Curculionidae</td>
<td>Cylas formicarius elegantus</td>
<td>Sweet potato weevil</td>
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<td>Sitophilus granarius</td>
<td>Wheat weevil</td>
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<td>Sitophilus oryzae</td>
<td>Rice weevil</td>
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<td>Sitophilus zeamais</td>
<td>Maize weevil</td>
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<td></td>
<td>Dermestidae</td>
<td>Trogoderma granarium</td>
<td>Khapra beetle</td>
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<td>Trogoderma variabile</td>
<td>Warehouse beetle</td>
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<td>Laemophloidae</td>
<td>Cryptolestes ferrugineus</td>
<td>Flat grain beetle</td>
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<td>Cryptolestes pusillus</td>
<td>Rusty grain beetle</td>
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<td></td>
<td>Silvanidae</td>
<td>Orzyaephalus surinamensis</td>
<td>Saw-toothed grain beetle</td>
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<td></td>
<td></td>
<td>Ahasverus advena</td>
<td>Foreign grain beetle</td>
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<td></td>
<td>Tenebrionidae</td>
<td>Tenebrio molitor</td>
<td>Mealworm beetles</td>
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<td>Tribolium castaneum</td>
<td>Red flour beetle</td>
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<td>Tribolium confusum</td>
<td>Confused flour beetle</td>
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<tr>
<td></td>
<td>Mycetophagidae</td>
<td>Typhaea stercorea</td>
<td>Hairy fungus beetle</td>
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<tr>
<td>Lepidoptera</td>
<td>Gelechiidae</td>
<td>Sitotroga cerealella</td>
<td>Angoumois grain moth</td>
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<td></td>
<td>Pyralidae</td>
<td>Amyelis transitella</td>
<td>Navel orangeworm</td>
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<td></td>
<td></td>
<td>Cadra cautella</td>
<td>Tropical warehouse moth</td>
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<tr>
<td></td>
<td></td>
<td>Ephhestia kuehniella</td>
<td>Mediterranean flour moth</td>
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<tr>
<td></td>
<td>Tortricidae</td>
<td>Plodia interpunctella</td>
<td>Indianmeal moth</td>
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<td>Cydia pomonella</td>
<td>Codling moth</td>
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<tr>
<td>Psocoptera</td>
<td>Liposcelididae</td>
<td>Liposcelis bostrychophila</td>
<td>Banded psocid (book louse)</td>
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<tr>
<td></td>
<td></td>
<td>Liposcelis entomophila</td>
<td>Grain psocid</td>
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<tr>
<td></td>
<td></td>
<td>Liposcelis paeta</td>
<td></td>
</tr>
</tbody>
</table>

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Upper limit of grain moisture content for safe storage

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Moisture content (% wet basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddy, rice (raw)</td>
<td>14</td>
</tr>
<tr>
<td>Rice (Parboiled)</td>
<td>15</td>
</tr>
<tr>
<td>Wheat Kabuligrun, Bengal gram</td>
<td>12</td>
</tr>
<tr>
<td>Sorghum, maize, barley, ragi, bajra, pulse, turmeric, wheat atta maida besan</td>
<td>12.5</td>
</tr>
<tr>
<td>Coriander, chillies</td>
<td>10</td>
</tr>
<tr>
<td>Groundnut pods</td>
<td>6-7</td>
</tr>
<tr>
<td>Mustard seed</td>
<td>5-6</td>
</tr>
</tbody>
</table>

Source: Agricultural Engineering Directory, 1983

Current control methods are based on the use of insecticides, which are generally the most effective management tools and provides the only feasible method of reducing insect pest populations to acceptable levels (Harein and Davis, 1992; Perez-Mendoza, 1999). Two fumigants are currently used for the protection of stored foods: phosphine and methyl bromide. However, the use of methyl bromide was banned according to the Montreal Protocol because it affects the ozone layer and is toxic to warm-blooded (Dansi et al., 1984). Phosphine remains one of the most commonly used insecticides.

More recently, there was an increasing interest in testing and using natural oils. Several plant species and their extracts are found to possess natural pesticide properties and are generally used as a traditional method to protect the grains. Plant-based insecticides are environment-friendly and safe for human health. Papachristos and Stamopoulos (2003) have reviewed the different deployment methods, i.e. as fumigants (Stamopoulos, 1991), contact insecticides (Saxena et al., 1992), repellents (Saim and Meloan, 1986), antifeedants (Harwood et al., 1990) and also deployment to influence some biological parameters, such as growth rate, life span and reproduction (Gunderson et al., 1985). The other insecticides used are diverse and include microbial pesticides, insect growth regulators and synergists (Daglish et al., 1995).

Locations of observed resistances in stored product insects in countries where the major studies on stored-product insect and insecticide resistances have been carried out since 1995
In the past few years, more than 504 species of insects and mites with insecticide resistance have been recorded, and there is still a steady increase in resistance to specific chemicals, with many species now resistant to several families of molecules (Georghiou, 1990; Lee, 2002a). Insects have successfully adapted to most insecticides by becoming physiologically or behaviorally resistant (Sawicki and Denholm, 1984). In post-harvest ecosystems, the development of insecticide resistance is of major concern in many countries. At least 11 species of stored-product insects are now known to have developed resistance to phosphine (Chaudhry, 2000), which has been linked to selection pressures by repeated ineffective fumigations in situations where phosphine gas was rapidly lost due to leakage (Halliday et al., 1983; Tyler et al., 1983; Benhalima et al., 2004).

**STORAGE STRUCTURES IN INDIA**

In India, grains are stored at farmers, traders and industrial levels. Traditional storage practices do not guarantee protection against major storage pests of staple food crops, leading to higher percentage of grain losses, particularly due to post-harvest insect pests and grain pathogens (Tefera et al., 2011). Grain storage structures are classified as follows:

- Conventional Structures
- Improved grain storage structures
- Commercial grain storage structures

**Conventional Structures**

In India, around 60-70% of food grains produced is stored at home level in indigenous storage structures (Kanwar and Sharma, 2003). Farmers use locally available raw materials to develop traditional structures differing in design, shape, size and functions. The materials used include paddy straw, wheat straw, wood, bamboo, reeds, mud, bricks, cow dung etc. The different conventional storage structures in use are:

- Straw storage structures
- Bamboo/Reed storage structures
- Masonary storage structures
- Earthen storage structures
- Underground storage structures

Storage pest is a problem in NE India due to its high humidity and rainfall. Farmers over the centuries have been relying on plants with insecticidal property to manage storage pests. The use of plant products to protect against storage pests is common ITK in NE India and many indigenous plants are used by different ethnic groups for storage pest protection. Worldwide many scientists and researchers are also working on finding a safe alternative to chemical pesticides that can be used both in farmer’s storage as well as in bulk storage. The farmers of NE India mostly depend on insecticidal plants to protect their grains from pests. Moreover, the storage structures are attached to the houses and
are not air tight as it is constructed from mud, bamboo, stones and plant materials, so become very prone to attack by insects, fungi and rodents.

In North Eastern hill region, a low cost medium term seed storage bin called RC Seed Bin has been developed by ICAR RC for NEH Region, Manipur Centre for the small farmers whose seed requirements are low. Three materials are used for the preparation of RC seed bin. The outermost layer is a bamboo mat bin, the next layer is the hessian bag while the innermost layer is again a hessian bag to protect the polythene layer from mechanical damage like punctures and ruptures. This bin could avoid the risk of losing the farmer’s variety in case of crop failure and save from additional expenses of seed production.

However, before storing the seeds should be well dried so that moisture content is reduced to 10-12% in cereals and 6-8% in oilseeds. Dessicants (charcoal) should also be well dried and immediately returned to air tight to prevent absorption of moisture from the air.

**Materials required and cost estimate of RC SEED BIN**

<table>
<thead>
<tr>
<th>Material</th>
<th>Cost (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bamboo bin (painted)</td>
<td>1200.00</td>
</tr>
<tr>
<td>Hessian</td>
<td>300.00</td>
</tr>
<tr>
<td>Polythene bag (0.7mm gauge)</td>
<td>400.00</td>
</tr>
<tr>
<td>Charcoal (0.25-0.50 cm size)</td>
<td>200.00</td>
</tr>
<tr>
<td>Others</td>
<td>150.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2250.00</strong></td>
</tr>
</tbody>
</table>

**Improved grain storage structures**

Pusa bin is one of the important improved methods of storage developed by IGSMRI (Indian Grain Storage Management and Research Institute). One design consist of the
floor and lower part of the walls made of burnt bricks with a layer of plastic sheeting inserted between two bricklayers. This protects the grain from moisture and prevents air from entering. A separate thatched roof around on top provides protection from sun and rain (Proctor, 1994). The other design of Pusa bin is made of double walls of masonry each 4.5 inch thick with polythene sheeting in between. The outer layers have steel reinforcement and the sides are plastered with cement (Jelle, 2003).

Commercial grain storage structures

In India, surplus food grains are accumulated in the warehouses owned by the Food Corporation of India (FCI), the Central warehousing corporation (CWC) or the State warehousing corporation (SWCs). They have a network of storage depots strategically located all over India (Singh, 2010). These depots include silos and an indigenous method developed by FCI, called Cover and Plinth (CAP). CAP storage are constructed with brick pillars to a height of 14 feet from the ground, with grooves into which wooden crates are fixed for the stacking of bags of food grains. Food grains such as wheats, maize, gram, paddy, and sorghum are generally stored in CAP storage for 6-12 month periods.

Control methods

1. HEAVILY USED METHODS

A) Physical control

Controlled atmospheres have been used to kill a wide range of quarantine and storage pests effectively, including members of the families Tephritidae, Tortricidae, Curculionidae, Miridae and Liposcelididae (Soderstrom et al., 1990; Ke and Kader, 1992; Whiting et al., 1992; Leong and Ho, 1995; Wang et al., 2000). Carbon dioxide is an important factor affecting the efficacy of controlled atmosphere treatments for pest mortality. Generally, the combination of low O₂ and high CO₂ leads to higher mortality than either gas alone because of the combined effects of anoxia and hypercarbia (Wang et al., 2000). CO₂ is efficient only when concentrations higher than 40% are maintained for long periods. Exposure periods longer than 14 days are required to kill the insects when the concentration of CO₂ in the air is below 40% (Kashi, 1981; Athie et al., 1998).

B) Fumigants

Two fumigants are currently used for the protection of stored foods: phosphine and methyl bromide. Methyl bromide (MeBr) fumigation of tree nuts was widely used to meet commercial phytosanitary requirements to control insect pests. However, it was used after careful consideration because of its very high toxicity to warm-blooded animals (Dansi et al., 1984), and its use was restricted due to its ozone depleting properties (FAO, 1975).

The most commonly used fumigant is phosphine, but its use was also limited because of increasing evidence that stored product insects were becoming resistant to the compound. This was observed in more than 45 countries (Bell and Wilson, 1995). Therefore, an effort is needed to develop a new compound to replace the conventional
fumigants. The application of fumigant mixtures has been recognized as a means of overcoming the disadvantages of using a single fumigant. A combination of fumigants is advisable, because none of the common fumigants, used singly, possesses the ideal characteristics (Navarro et al., 1986; Athie et al., 1998).

C) Organochlorines

Organochlorines are persistent in the environment and are known for bioaccumulating or building up in sediments, plants and animals. DDT was the most widely used insecticide to protect stored maize in Brazil until 1985 (Guedes et al., 1995). Topical application bioassays of DDT and lindane were undertaken with 11 field strains of maize weevil, *Sitophilus zeamais* Motschulsky, collected from nine states in Mexico (Perez-Mendoza, 1999) in order to compare them with new insecticide treatments. Nowadays, both DDT and lindane are officially withdrawn.

D) Organophosphates

When the use of organochlorines was restricted, they were replaced by organophosphorus compounds, like malathion, for the control of stored grain insects. Organophosphates replaced DDT, but the extensive use of malathion for pest control on stored cereals has resulted in a worldwide resistance of several species like *Tribolium castaneum* in 1961 in Nigeria or *Sitophilus zeamais* in Brazil (Guedes et al., 1995). The use of malathion decreased significantly after control failures in stored grain. Thus, this compound has been replaced by other organophosphorous, such as pirimiphos-methyl, chlorpyrifos-methyl, dichlorvos, etrimfos and fenitrothion.

E) Pyrethroids

Organophosphorous have been replaced by pyrethroids, such as phenothrin, deltamethrin, cypermethrin, permethrin with/without piperonyl butoxide. The deltamethrin shows a great efficacy against *S. zeamais* (Guedes et al., 1995). Some other chemical alternatives such as the α-cyano phenoxybenzyl cyclopropanecarboxylate pyrethroids and, particularly, deltamethrin synergized with piperonyl butoxide, which is an inhibitor of P450s, have then been used (Bengston et al., 1987; Arthur, 1994).

2. ALTERNATIVE METHODS

A) Semiochemicals

Most semiochemicals are oils extracted from plants with pesticide properties. Essential oils are easily distilled and may act as fumigants against stored product insects (Stamopoulos, 1991), contact insecticides (Saxena et al., 1992), repellents (Saim and Meloan, 1986), antifeedants (Harwood et al., 1990) and may also affect some biological parameters, such as growth rate, life span and reproduction (Gunderson et al., 1985; Papachristos and Stamopoulos, 2003). The monoterpenes cineol and limonene, which are commonly found in leaves of *Eucalyptus globulus* Labidalliere, *E. camaldulensis* Denhardt and *E. cameroni* Blakely and McKie, and in peel of *Citrus aurantium* L. and *Citrus limonum*
Risso have a significant insecticidal effect (Prates et al., 1998). These substances are toxic by penetrating the insect body via the respiratory system (fumigant system), the cuticle (contact effect) or the digestive system (ingestion effect) (Prates et al., 1998). The toxicity of the evaporated substance is sufficient to knock down and kill insects, in a period of time as short as 24 h (Prates et al., 1998).

Essential oils are potential alternatives to current fumigants because of their low toxicity to warm-blooded mammals, their high volatility and their fumigation toxicity to stored grain insect pests (Shaaya et al., 1991, 1997; Regnault-Roger et al., 1993). In a fumigation toxicity test of essential oils and monoterpenes, the alcohol and phenolic monoterpenes showed the greatest activity against *Oryzaephilus surinamensis* (L.), the sawtoothed grain beetle (Shaaya et al., 1991; Lee et al., 2000b).

Some essential oils have an acute toxicity, a repellent action, a feeding inhibition, or harmful effects on the reproductive system of insects. Additionally, secondary metabolites from higher plants have recently been used as pesticides or models for new synthetic pesticides, as, for instance, toxaphene (insecticide and herbicide) and cinmethylin (herbicide) (Prates et al., 1998). Those chemicals were developed from plant-derived products such as terpenoids that can be found in essential oil secreted by the glandular trichomes of Artemisia (Compositae) or closely related genera. Pine oil, a by-product of the sulphate wood pulping industry, has the monoterpane α-terpineol among its major constituents. These substances present toxicity to the house fly (*Musca domestica* L.), German cockroach (*Blatella germanica* L.), rice weevil (*Sitophilus oryzae* L.), red flour beetle (*Tribolium castaneum* Herbst) and Southern corn rootworm (*Diabrotica unidecimpunctata howardi* Barber) (Rice and Coats, 1994a, b).

**B) Microbial insecticides**

Microbial pesticides, such as spinosad or *Bacillus thuringiensis*, are biopesticides composed of a particular species of microbe, generally producing one or several toxins that will kill the pest. Microbial pesticides are supposed to be very selective and affecting the target pest (Abdel-Razek et al., 1999; Hertlein et al., 2011).

**C) Botanical insecticides**

The combination of applications of neem seed oil and use of resistant cowpea varieties appears to have great potential for the management of *Callosobruchus maculatus* in stored cowpea with the reduction of egg-laying and adult emergence (Lale and Abdulrahman, 1999; Lale and Mustapha, 2000). In addition, their joint use in bruchid control would be likely to delay the emergence of biotypes of the bruchid that are capable of breaking down resistance in cowpea varieties or strains of *C. maculatus* with resistance to neem seed oil. Essential oils have low toxicity to warm-blooded animals, high volatility, and toxicity to stored grain insect pests (Shaaya et al., 1991, 1997; Regnault-Roger et al., 1993).
D) Natural proteins

Natural insecticidal compounds from plant seeds have been detected and characterized (Soares et al., 2007; Velten et al., 2007). The arcelin from common beans *Phaseolus vulgaris* L. inhibited the development of *Acanthoscelides obtectus*; the seeds treated with arcelin delayed the growth of immatures (Velten et al., 2007). In the same way, the weight of *C. maculatus* larvae has been influenced, and decreased, by globulins and albumins from *Luetzelburgia auriculata* (Allemao). Depending of the concentrations, insecticidal effects could be observed (Soares et al., 2007).

E) Insect growth regulators

Insect growth regulators (IGR) act in the insect to disturb a physiological regulatory process essential in the normal development of the insect or its progeny (i.e. emergence from pupae to adult). IGR insecticides are selective because of their narrow spectrum of activity, low mammalian toxicity, and are considered integrated pest management compatible (Ayalew, 2011). The efficacies of chlorpyrifos-methyl, methoprene and piperonyl butoxide used as synergists have been tested on maize against resistant strains of *Sitophilus zeamais*, *S.oryzae*, *R. dominica*, *T. castaneum* and *O. surinamensis* and confirmed the efficacy of a combination of chlorpyrifos-methyl and methoprene and mentioned that methoprene alone could be used as part of a resistance management strategy against *R. dominica* (Daglish et al., 1995).

Daglish (2008) showed that binary combinations of spinosad, chlorpyrifos-methyl and s-methoprene could control resistant strains of *S. oryzae*, *R. dominica*, *T. castaneum*, *O. surinamensis* and *Cryptolestes ferrugineus*. He also demonstrated the difficulties of finding the right combinations of products against a wide range of species regarding the development of resistance in different countries. The effects of N, N-diethyl-m-toluamide (DEET) known as an insect repellent (Watson and Barson, 1996) have also been tested on different strains of *O. surinamensis*. The results showed an avoidance behaviour during the first seven hours, which disappeared after 24 h for all the strains.

F) Others

Integrated pest management (IPM) systems to control insect pests should combine parasitoids and host plant resistance. The contribution of the combination of certain arcelin-enriched bean varieties with the parasitoid proved to be of significant advantage. The control system should be further optimized to promote host-feeding of the parasitoid (Schmale et al., 2003). The main difficulties associated with the introduction of alternative control methods are a low acceptance by farmers and consumers, e.g. treatment of the grain with oil or ashes, or their high costs, e.g. storing of the grain in metal bins (Schmale et al., 2003).
References
AAEA and CAES Joint Annual Meeting, Washington, DC, USA, 4–6 August 2013.


Rice, P.J. and Coats, J.R. (1994b) Insecticidal properties of several monoterpenoids to the housefly (Diptera, *Muscidae*), red flour beetle (Coleoptera: *Tenebrionidae*), and southern corn rootworm (Coleoptera: *Chrysomelidae*). *Journal of Economic Entomology* 87, 1172–1179.


Application of biocontrol agents for management of plant diseases in climate smart agriculture

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Biocontrol agents are the important microorganisms used for eco-friendly management of plant pathogens/diseases of crop plants. The importance of bioagents like *Trichoderma* spp, *Pseudomonas fluorescens*, *Bacillus subtilis* use in plant diseases management. It has realized to overcome the resistance against pesticides in the pathogens. The production of agricultural commodities free of the pesticides in the wake of globalization of trade, checking of the pollution of hazardous chemical in the precious natural resources etc. Beside the bioagents have other many qualities as to trigger systemic resistance in plants against the pathogens, enhancing the crop growth due to uptake of the essential micronutrients. Beyond the doubt the bioagents have been very well proved that they are very useful component of integrated disease management and integrated farming system.

Biological control has become an attractive alternative strategy for the control of plant diseases to reduce the excessive use of agrochemicals and its health hazards under integrated farming system. Among the variety of biological control agents available for use, screening of potent biocontrol agents is necessary for their further development and commercialization for management of plant diseases. Biocontrol agents comprise of multiple beneficial characters such as rhizosphere competence, antagonistic potential, and ability to produce antibiotics, lytic enzymes and toxins. These biological control activities are exerted either directly through antagonism of soil-borne pathogens or indirectly by eliciting a plant-mediated resistance response. The mechanisms of biocontrol involve antibiosis, parasitism, competition for nutrients and space, cell wall degradation by lytic enzymes and induced disease resistance.

**Mode of action of biocontrol agents for management of plant diseases:** Biological control agents (BCAs) reduce disease of the target crop usually by one or more of the following mode of action: Antagonism, hypovirulence and the induction of host resistance. The mechanisms of action of antagonist against plant pathogens/diseases has been summarized in Fig.1. Following are five important components of mechanisms of antagonist.
1. **Antibiosis:**

Antibiosis is that antagonistic condition in which is suppression of pathogenic microorganism due to secretion of toxic or inhibitory compound (Antibiotic) by other organisms. Such compound rage from hydrogen cyanide (HCN) to enzyme and the microorganism involved are often species of *Trichoderma* and *Gliocladium* among fungi and *Bacillus* and *Pseudomonas* among bacteria. The genus *Trichoderma* comprises a large number of species some of which act as biological control agents through one or more mechanisms. *Trichoderma* strains exert control against fungal phytopathogens either indirectly by competing for nutrients and space, modifying the environmental condition, promoting plant growth, plant defensive mechanisms and antibiosis, or directly by mechanisms such as mycoparasitism. Activation of each mechanism implies the production of specific metabolites, such as plant growth factors, hydrolytic enzymes, siderophores, antibiotics, and permeases. Specific strains of fungi in the genus *Trichoderma* colonize and penetrate plant root tissues and initiate a series of morphological and biochemical changes in the plant, considered to be part of the plant defense response, which subsequently leads to induced systemic resistance (Bailey and Lumsden, 1998). Antibiosis occurs during interactions with other microorganisms involving low molecular weight diffusible volatile and nonvolatile toxic metabolite compounds or antibiotics like harzianic acid, alamethicins, tricholin, peptaibols, antibiotics, 6-penthal-pyrone, massoilactone, viridin, gliovirin, glisoprenins, heptelicid.
acid and others. Mycoparasitism, the direct attack of one fungus on another, is a very complex process that involves sequential events, including recognition, attack, subsequent penetration, and killing of the host. The cell wall degrading enzymes (CWDEs) of *Trichoderma* such as different chitinolytic enzymes, glucanases and proteases are considered important in mycoparasitism. Chitin and -1, 3 glucan are the main structural components of the fungal cell wall and chitinases, and -1, 3 glucanases have been proposed as the key enzymes in the degradation of cell wall during mycoparasitism against phytopathogenic fungi. Genes encoding these enzymes are being used to impart resistance to various fungal plant pathogens. In addition to the direct action of hydrolytic enzymes on the cell wall of an invading pathogen. The first commercial biocontrol agent was probably strain K84 of *Agrobacterium* which has been used successfully to control crown gall disease by *Agrobacterium tumefaciens* by agrocin 84 antibiotic. Strain of *Pseudomonas* produce several toxic inhibitory compounds including phenazine 1-carboxylic acid, phenazine-1-carboximide, anthranilic acid, diacetyl phloroglucinol, pyoluteorin, pyrrolnitrin and viscosinamide. Table 1 shows some antibiotic products of biological control agents.

**Table 1: Some antibiotics products of BCAs, their class, source microorganism and target microorganism**

<table>
<thead>
<tr>
<th>Class of compound</th>
<th>Antibiotic product</th>
<th>Source of microorganism</th>
<th>Target microorganism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amino acid derived</td>
<td>Bacilysin</td>
<td><em>Bacillus subtilis</em></td>
<td>Yeast and Bacteria</td>
</tr>
<tr>
<td>Aminopolyol</td>
<td>Zwittermicin A</td>
<td><em>Bacillus cereus</em></td>
<td>Fungi</td>
</tr>
<tr>
<td>Cyanide</td>
<td>HCN</td>
<td><em>Pseudomonas fluorescens</em></td>
<td>Fungi</td>
</tr>
<tr>
<td>Enzyme</td>
<td>Chitinase</td>
<td><em>Serratia marcescens</em></td>
<td>Fungi</td>
</tr>
<tr>
<td>Fatty acid</td>
<td>Laetisaric acid</td>
<td><em>Laetisaria aryalis</em></td>
<td>Fungi</td>
</tr>
<tr>
<td>Furanone</td>
<td>3-(1-hexenyl)-5-</td>
<td><em>Pseudomonas aureofaciens</em></td>
<td>Fusarium spp</td>
</tr>
<tr>
<td></td>
<td>methyl-2-((hp)-</td>
<td></td>
<td><em>Rhizoctonia solani</em></td>
</tr>
<tr>
<td></td>
<td>furanone</td>
<td></td>
<td><em>Thielaviopsis basicola</em></td>
</tr>
<tr>
<td>Lipopeptide</td>
<td>Iturin</td>
<td><em>Bacillus subtilis</em></td>
<td>Fungi and Bacteria</td>
</tr>
<tr>
<td></td>
<td>Surfactin</td>
<td><em>Bacillus subtilis</em></td>
<td>Fungi and Bacteria</td>
</tr>
<tr>
<td></td>
<td>Viscosinamide</td>
<td><em>Pseudomonas fluorescens</em></td>
<td>DR 54</td>
</tr>
<tr>
<td></td>
<td>AFC-BC11</td>
<td><em>Burkholderia cepacia</em></td>
<td><em>Rhizoctonia solani</em></td>
</tr>
<tr>
<td>Nicotinic acid</td>
<td>2- methylheptyl</td>
<td><em>Streptomyces sp.</em></td>
<td><em>Rhizoctonia solani</em></td>
</tr>
<tr>
<td>derived</td>
<td>isoniconate</td>
<td></td>
<td><em>Fusarium spp.</em></td>
</tr>
<tr>
<td>Necliotide</td>
<td>Agrocin 84</td>
<td><em>Agrobacterium strain K84</em></td>
<td>Agrobacterium tumefaciens</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Agrobacterium strain1026</em></td>
<td></td>
</tr>
<tr>
<td>Peptide</td>
<td>Dimerum (a</td>
<td><em>Trichoderma virens</em></td>
<td>Fungi</td>
</tr>
<tr>
<td></td>
<td>siderophores)</td>
<td><em>Brevibacillus brevis</em></td>
<td>Botrytis cinerea</td>
</tr>
<tr>
<td></td>
<td>Gramicidin S</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. **Competition:** This process is considered to be an indirect interaction whereby pathogens are excluded by depletion of a food base or by physical occupation of site (Lorito *et al.*, 1994). Generally, nutrient competition has been believed to have an important role in disease suppression, although it is extremely difficult to obtain conclusive evidence. Biocontrol by nutrient competition can occur when the biocontrol agent decreases the availability of a particular substance thereby limiting the growth of the pathogen. Particularly, the biocontrol agents have a more efficient uptake or utilizing system for the substance than do the pathogens (Handelsman and Parke, 1989; Harman and Nelson, 1990 & 1994). For example, iron competition in alkaline soils may be a limiting factor for microbial growth in such soils (Leong and Expert., 1989). Some bacteria, especially fluorescent *Pseudomonads* produce siderophores that have very high affinities for iron and can sequester this limited resource from other microflora thereby preventing their growth (Loper and Buyer, 1991).

*Trichoderma* species are generally considered to be aggressive competitors, grow very fast and rapidly colonize substrates to exclude pathogens such as *Fusarium spp*. Rhizosphere competence, following seed treatment, is an important strategy to create a zone of protection against pathogens (Howell, 2003). *Trichoderma* species, either added to the soil or applied as seed treatments, grow readily along with the developing root system of the treated plants (Ahmad and Baker, 1987). Soil treatments with *T. harzianum* spores suppressed infestations of *Fusarium oxysporum f. sp. vasicola* and *F. oxysporum f. sp. melonis*. Competition was a proposed mechanism, although it was not proven to be the main activity.

Starvation of most common cause of death for microorganisms, so that competition for limiting nutrients results in biological control of fungal phytopathogens (Chet *et al.*, 1997). In most filamentous fungi, iron uptake is essential for viability, and under iron
starvation, most fungi excrete low molecular weight ferric-iron specific chelators, termed siderophores, to mobilize environmental iron (Eisendle et al., 2004). Subsequently, iron from the ferri-siderophore complexes is recovered via specific uptake mechanisms. In *Aspergillus fumigatus* and *Aspergillus nidulans*, siderophore biosynthesis is negatively regulated by carbon source (Eisendle et al., 2004). In *Ustilago maydis*, gene products related to iron uptake affect the development of plant disease (McIntyre et al., 2004). Some *Trichoderma* isolates produce highly efficient siderophores that chelate iron and stop the growth of other fungi (Chet and Inbar; 1994). For this reason, soil composition influences the bio-control effectiveness of *Pythium* by *Trichoderma* according to iron availability. In addition, *T. harzianum* T35 control effectiveness of *Pythium* by *Trichoderma* according to iron availability. In addition, *T. harzianum* T35 controls *Fusarium oxysporum* by competing for both rhizosphere colonization and nutrients, with bio control becoming more effective as the nutrient concentration decreases (Tjamos et al., 1992). Competition has proved to be particularly important for the bio-control of phytopathogens such as *Botrytis cinerea*, the main pathogenic agent during the pre and post-harvest in many countries (Latorre et al., 2001). The extraordinary genetic variability of this fungus makes it possible for new strains to become resistant to essentially any novel chemical fungicide on which it is exposed (Latorre et al., 2001). The advantage of using *Trichoderma* to control *B. cinerea* is the coordination of several mechanisms at the same time, thus making it practically impossible for resistant strains to appear. Among these mechanisms, the most important is nutrient competition, since *B. cinerea* is particularly sensitive to the lack of nutrients.

### 3. Mycoparasitism:

Most of plant diseases are due to fungi and large number of fungi parasitizing fungi are known. When one fungus parasitizes another the phenomenon is called mycoparasitism, hyperparasitism, direct parasitism or interfungus parasitism. It is a process of direct attack of one fungus on another. It is a very complex process that involves sequential events, including recognition, attack and subsequent penetration and killing of the host. During this process *Trichoderma* secretes cell wall degrading enzymes (CWDEs) including cellulases, chitinases and glucanases that hydrolyse the cell wall of the host fungus (Fig.2), subsequently releasing oligomers from the pathogen cell wall (Howell 2003). It is believed that *Trichoderma* secretes hydrolytic enzymes at a constitutive level and detects the presence of another fungus by sensing the molecules released from the host by enzymatic degradation (Harman et al., 2004; Lorito et al., 2006; Wood and Lorito, 2007).
Mycoparasitism involves morphological changes, such as coiling and formation of appressorium like structures, which serve to penetrate the host and contain high concentrations of osmotic solutes such as glycerol (Mcintyre et al., 2004). *Trichoderma* attaches to the pathogen with cell wall carbohydrates that bind to pathogen lectins. Once *Trichoderma* is attached, it coils around the pathogen and forms the appresoria. The following step consists of the production of pathogenesis related enzymes and peptaibols (Howell, 2003), which facilitate both the entry of *Trichoderma* hyphae into the lumen of the parasitized fungus and the assimilation of the cell wall content.

**Induction of Host Resistance:** Disease suppression through the induction of resistance in host in an alternative and quite difference, mode of action of biological agents. It has been found during recent years that rhizosphere bacteria (rhizobacteria) applied to seed or roots induce systemic resistance response expressed against pathogen infecting aerial tissues. For instance, when *Pseudomonas fluorescens* was applied to roots of carnation and the stems were inoculated one week later with *Fusarium oxysporum f.sp. dianthi*, the vascular wilt causing fungus, the incidence of disease was reduced as a result of increase the resistance of the host. Similarly the resistance was introduced to leaf pathogens such as *Colletotrichum orbiculare* and *Pseudomonas syringae* in cucumber and bacterial blight (*Pseudomonas syringae pv. phaseolicola*) in bean with the inoculation of biological control agents. This induction of resistant as appeared was presumably due to the production of a signal molecules by the colonizing BCA, which activates systemic acquired resistance (SAR) pathway resulting in release of pathogenesis-related (PR) proteins. More recent evidences suggest that different biocontrol agents (Bacteria) may be operate through different pathways district from the above mentioned typical systemic acquired resistance response, when the bioactive strain of *Pseudomonas fluorescens* was applied to the roots of Arabidopsis plants, resistance to both a vascular wilt fungus and foliar bacterial pathogens was subsequently increased but there was no accumulation of pathogenesis related (PR) proteins or salicylic acid in disease reaction.
The ability of *Trichoderma* strains to protect plants against root pathogens has long been attributed to an antagonistic effect against the invasive pathogen (Chet *et al.*, 1997). However, these root fungus associations also stimulate plant defensive mechanisms. Strains of *Trichoderma* added to the rhizosphere protect plants against numerous classes of pathogens, those that produce aerial infections, including viral, bacterial and fungal pathogens, which points to the induction of resistance mechanisms similar to the hypersensitive response (HR), systemic acquired resistance (SAR), and induced systemic resistance (ISR) in plants (Harman, 2006; Harman *et al.*, 2004). At a molecular level, resistance results in an increase in the concentration of metabolites and enzymes related to defensive mechanisms, such as the enzymes phenylalanine ammonio lyase (PAL) and chalcone synthase (CHS), involved in the biosynthesis of phytoalexins (HR response), chitinases and glucanases. These comprise pathogenesis related proteins (PR) (SAR response) and enzymes involved in the response to oxidative stress (Stacey and Keen, 1999).

**Enhancement of rhizosphere colonization of biocontrol agents:** Root colonization ability of biocontrol agents and potential to survive and proliferate along growing plant roots over a considerable period, in the presence of the indigenous micro flora results in intimate associations that directly provide a selective adaptation to plants towards specific ecological niches. Also, the ability of biocontrol agent to colonize specific substrates or sites, whether a seed, root, shoot area, stump or fruit surface, provides protection to infection site from pathogen attack. However, they are effective only when provided with an additional competitive advantage, such as high initial cell numbers, earlier establishment than the pest or pathogen, or the production of antibiotic substances. Therefore, rhizosphere competence is considered as a prerequisite for effective biological control. Understanding root-microbe communication, as affected by genetic and environmental determinants in spatial and temporal contexts, will significantly contribute to improving the efficacy of these biocontrol agents. Once biocontrol agents establish on the site, the mechanism of antagonism might be competition for nutrients, space, siderophores production, antibiosis and production of hydrolytic enzymes or other active substances.

Research on the appropriate fungi or bacteria, individually or in combination with other microbes can be formulated onto plant seeds for enhanced colonization and or biocontrol activity. Perhaps the most exciting use of genetic approaches in colonization research is the genetic manipulation of biocontrol agents to enhance the colonization of the subterranean portion of plant by these biocontrol agents. Agriculture situation may occur where it is advantageous to use biocontrol agents that are nonpersistent in the environment. Genetic approach has been used to construct nonpersistent mutant of biocontrol bacteria. These mutants are ideal candidates for genetic containment strategies for genetically improved strains. Finally, genetic approaches are being devised to enhance colonization and microbial activity by plant-beneficial bacteria.
Application of biocontrol agents for management of plant diseases

1. Application of biocontrol agents in management of vegetable diseases: Potato (Solanum tuberosum) is one of the most important vegetable crops in India. Potato plants are suffering with many fungal, bacterial and viral diseases and its causes significant yield losses like late blight (Phytophthora infestans), common scab (Streptomyces scabies), dry rot (Fusarium spp.), black scurf and bacterial wilt (Ralstonia solanacearum). Recently Phytophthora infestans showed resistance against fungicides under this situation biopesticide is alternative approach for management of plant diseases. The antagonistic fungal population may be considered as one of the factors which also plays an important role in germination and yield of potato (Dwivedi, 1988). Methods for friendly potato disease management allows organic tropical Indian production systems to prosper though there are reports of use Trichoderma bioformulations in management of late blight of potato in North eastern India (Selvakumar, 2008; Basu, 2009). Success in mycoparasitism of potato scurf pathogen (R. solani) by use of T. harzianum by Pandey and Pundhir (2013) further can be taken as the future of biological management of this important disease.

Cauliflower (Brassica oleracea L. var. botrytis) and cabbage (Brassica oleracea L. var. capitata) are the most important winter vegetables of India. Major pathogens which cause crop losses are club root caused by Plasmodiophora brassicae, black rot by Xanthomonas campestris, wire stem by Rhizoctonia solani, leaf spot by A. brassicaceae, leaf blight by A. brassicola, damping off by R. solani, Pythium, Phytophthora, Corticium and Fusarium. Antagonistic potential of Trichoderma and Aspergillus species was evaluated on Sclerotinia sclerotiorum causing rots in cabbage and cauliflower by Sharma et al., (2001) and further the role of Trichoderma spp. in an IDM programme on the management was confirmed against Sclerotinia sclerotiorum (Sharma et al., 2001; Zewain et al., 2004). Sharma and Sain (2005) reported the use of bio-agents and abiotic compounds for inducing resistance against damping-off of cauliflower caused by P. aphanidermatum. Zewain et al., (2005) evaluated an integrated disease management programme on stalk rot of cauliflower. In a study on the effect of soil solarization on sclerotial viability of S. sclerotiorum of cauliflower, Sharma et al., (2005) observed the reduction in viability of sclerotial bodies which also promoted the biocontrol activity. In a study on integrated management of major pests of cauliflower by Ahuja et al., (2012), decreased disease incidence and higher curd production was observed in the IPM fields applied with talc based formulation of T. harzianum adapted for local conditions as compared to conventional non IPM fields resulting in sustainable and stable pest control.

Chilli (Capsicum annum) is another important vegetable crop also used as a spice and rich in vitamins C, A and B. Among the fungal diseases, damping off caused by S. rolfsii, F. oxysporum, Pythium spp., R. solani and Phytophthora sp. are widely prevalent in the country. Several groups revealed that isolates of T. harzianum, T. viride (TVC3) and T. hamatum are effective bio-control agents against anthracnose and damping-off and chilli
dieback disease. In a study performed by Sharma et al., (2004) on integrated
management of chilli dieback and anthracnose, the disease reduction was found to be
highest in IPM module followed by chemical module. In another study, positive
interaction of T. harzianum with R. solani was observed in the rhizospheres of chilli
cultivars by Mathur et al., (2006) indicating its potential for biological management of
chilli diseases. The biocontrol potential of Trichoderma spp. against important soil-borne
diseases of vegetable crops was evaluated by (Kapoor, 2008). Kaur et al., (2006)
demonstrated the in vitro effect of Trichoderma species on C. capisci causing fruit rot. An
in vitro experiment was also conducted to evaluate the effect of eight isolates of
Trichoderma species by Muthukumar et al., (2011) and found a Trichoderma isolate TVC3
was able to inhibit the mycelial growth of pathogen as well as promoting the plant
growth. In another study, the concept of using coco-peat enriched with T. harzianum was
suggested for better plant growth and reduced incidence of tomato wilt and chilli root
rot while raising disease free and healthy seedlings which also reduced wilt incidence in
tomato (Sriram et al., 2010). In another study, fungal isolates were tested for biocontrol
of anthracnose disease in greenhouse and field by Vasanthakumari et al., (2013) who
found that the test antagonistic fungi- F. oxysporum, C. globosum and T. harzianum could
be used to control anthracnose and promote plant growth, and increase yield of chilli in
field.

Combination of seed/root application of T. harzianum or P. fluorescens with soil
solarization was found effective in management of diseases of tomato, brinjal and
capsicum way back in 1990’s. Tomato (Solanum lycopersicum) is an important vegetable
crop grown in almost all parts of India. However, the crop is susceptible to a wide range
of diseases like late blight caused by P. infestans, early blight by A. solani, wilt caused by
F. oxysporum f.sp. lycopersici, damping off by P. aphanidermatum, collar rot by S. rolfsii,
bacterial leaf spot by Xanthomonas campestris pv. vesicatoria, and bacterial wilt by
Ralstonia solanacearum. Among them, the diseases caused by soil-borne fungi or fungal
like pathogens remained a challenging task to manage. The usage of a number of species
of Trichoderma, T. harzianum, T. polysporum, T. virens and T. viride not only reduced the
disease incidence but also increased the yield of vegetable crops. In control of collar rot
of tomato by Trichoderma isolates (Dutta and Das, 2002), T. harzianum was the most
inhibitory to S. rolfsii showing 61.5% inhibition of the mycelial growth of the pathogen. In
vitro studies have shown that T. harzianum isolates inhibited the growth of P.
aphanidermatum up to 50% and found to be compatible with Bavistin, Captan and
Vegfrugard, respectively (Sharma et al., 2003). Role of Trichoderma species in systemic
resistance of tomato and cauliflower against stalk rot pathogen S. sclerotiorum was
documented (Sharma and Sain, 2004). The observations showed the superiority of T.
harzianum isolates over T. viride isolates in induction of systemic resistance. The effect of
Trichoderma species similar in tomato and cauliflower further confirmed that the
induction of the plant defence might also play a role in biocontrol. The effect of
antagonists on damping-off of tomato was widely studied by many other workers as well.
Manoranitham et al., (2000) reported that the application of *T. viride* and *P. fluorescens* effectively checked the pre-emergence and post-emergence damping off of tomato caused by *P. aphanidermatum* under pot culture experiments. Likewise, Sharma and Sain (2003) evaluated commercial and laboratory formulations of bioagents and plant nutrients against wilt of tomato. Jayaraj et al., (2006) developed a carrier based formulation of *T. harzianum* strain M1 for control of damping-off of tomato caused by *P. aphanidermatum*. The biocontrol potential of *Trichoderma* spp. against important soil borne diseases of vegetable crops has been reviewed (Kapoor, 2008). Baranwal et al., (2011) reported the management of tomato wilt caused by *F.o. f.sp. lycopersici* by using bioagents and organic amendments.

Onion (*Allium cepa*) is another important vegetable crop of India. Six major diseases *Alternaria alternata* causing foliar blight of onion, *Alternaria porri* causing purple blotch of onion, damping-off and basal rot by *F.o. f.sp. cepae* and *Pythium sp*, white rot by *S. rolfsii* and black mould by *A. niger* were found to be associated with the crop. Control of *A. porri* causing purple blotch of onion has been widely studied. Effective isolates of *T. harzianum* i.e.Th3, Th-30 of *T. harzianum* and Tv-12, Tv-15 of *T. viride* were reported to express high level of disease reduction and growth promotion in susceptible onion (Prakasam and Sharma, 2012). Biological management and IDM of foliar blight have also been reported (Shahnaz et al., 2013). In vitro evaluation of plant extracts, bio-agents and fungicides against purple blotch and Stemphylium blight of onion suggested that *T. viride* was effective in inhibiting the growth of pathogen (Mishra and Gupta, 2012).

### 2. Application of biocontrol agents for management of oilseed crop diseases

Indian mustard *Brassica juncea* (L.) is one of the major oilseed crops cultivated in India. Several researches were focused on the eco-friendly approaches of managing these major diseases employing *Trichoderma*. In an in vitro study *T. viride* performed along with fungicides mancozeb and carbendazim and showed superior result against mycelial growth of *Alternaria brassicae* over control (Meena et al., 2004). A systematic study was carried out by Gaur et al., (2010) where seed and foliar spray treatments of mixed formulation of *T. hamatum* (HP20) and *T. viride* (Tv-1) were found superior in field trials. A comparative study on the effect of chemicals, aqueous extracts of plants, cow urine and bio-agents, *T. harzianum*, *P. fluorescence* against the blight revealed that their efficiencies were at par with chemicals (Meena et al., 2011).

Soybean (*Glycine max* L.) is the third most important oilseed crop. Integrated management schedules of root, seed and foliar diseases have been worked out by several researchers. Khodke and Raut (2010) worked on the management aspects of root rot or collar rot of soybean by using seed treatment and soil application of fungicides, *Trichoderma* spp. and their combinations. Maximum germination was achieved due to seed treatment with Thiram and Carbendazim and *Trichoderma* spp. Potential of *Trichoderma* and plant growth promoting rhizobacteria, *P. fluorescens* were tested under glasshouse and field conditions against many soil-borne plant pathogens viz., *R. solani*, *S.*
rolfsii and *M. phaseolina* responsible for root and stem rot disease of soybean (Mishra et al., 2011). *Trichoderma* species inhibited the growth of oilseed-borne fungi like *Aspergillus flavus*, *Alternaria alternata*, *Curvularia lunata*, *Fusarium moniliforme*, *Fusarium oxysporum*, *Rhizopus nigricans*, *Penicillium notatum* and *Penicillium chrysogenum* which affects oil seed crops like soybean, sesame and sunflower (Jat and Agalave, 2013). Pant and Mukhopadhyay (2001) reported the management of seed and seedling rot complex of soybean caused by *R. solani* using biocontrol agents *Gliocladium virens* and *T. harzianum*, in a combination study with fungicides and *Trichoderma* spp.

Groundnut (*Arachis hypogaea* L.) yield less due to the high disease incidence. Though more than 55 pathogens have been reported to affect the crop, few diseases like early leaf spot (*Phaeoisriopis arichidicola*), late leaf spot (*Phaeoisriopis personata*), rust (*Puccinia arichidis*), collar rot (*A. niger van tiegham*), stem rot (*S. rolfsii*), root rot (*M. phaseolina*) and alfalfa root (*Aspergillus flavus*) are recognized to be economically important and have been biologically managed by deploying. Sreedevi *et al.*, (2012) optimized the substrate for chitinase production in *T. harzianum* isolated from rhizospheric soils of healthy groundnut plants and found that enzyme production was significantly influenced by the chitin concentration and nitrogen source incorporated into the medium used for the growth. Maximum chitinase activity was observed at 1% chitin and peptone as nitrogen source, chitinase activity of *T. harzianum* was maximum after fifth day of growth. Production of chitinase enzyme was enhanced by polysaccharides contained in the mycelium of *M. phaseolina*. Induce systemic resistance study was carried out by Sreedevi *et al.*, (2011), who tested antagonistic activity of *T. harzianum* isolated from the rhizosphere of groundnut under in vitro. They also studied biochemical changes in *T. harzianum* treated plants, *M. phaseolina* inoculated plants and healthy plants at different stages of infection. The observations revealed that *T. harzianum* was capable of inducing systemic resistance against *M. phaseolina* by eliciting the production of defense enzymes. Under field studies, Sharma *et al.*, (2012) carried out field trails in Rajasthan, on the groundnut root rot disease caused by multiple pathogen complex mainly *A. niger*, *A. flavus*, *S. rolfsii*, *Thievaaliopsis basicola*, *R. solani* and *P. aphanidermatum* by the application of *T. harzianum* in the form of powder and liquid bio-formulation and found it effective in controlling disease in field. Kishore *et al.*, (2001) reported the antagonistic potential of 16 *Trichoderma* isolates against *A. niger* in crown rot of groundnut in vitro and under greenhouse conditions and found them superior in comparison to fungicide treatment. Rakholiya and Jadeja (2010) tested three fungicides viz., mancozeb, tebuconazole and vitavax power, two bioagents viz., *T. harzianum* and *P. fluorescens* and one insecticide (chloropyriphos) against stem and pod rot of groundnut caused by *S. rolfsii* and found that *T. harzianum* provided maximum protection to the crop.

3. Application of biocontrol agents for management of pulses crop diseases: Chickpea (*Cicer arietinum* L.) is one of the most popular pulses in many regions of the world. It
contributes 50% of the major pulse production in India. Chickpea is frequently attacked mainly by a wilt caused by *Fusarium oxysporum f. sp. ciceri*, stem rot by *Sclerotinia sclerotiorum* and damping off caused by *R. solani* which are worldwide in distribution. Chand and Singh (2005) tried *T. viride*, *G. virens* and *T. harzianum* in combination along with plant extracts, viz., aak (*Calotropis procera*), eucalyptus (*Eucalyptus globulus*), jatropha (*Jatropha multifida*), neem (*Azadirachta indica*), garlic (*Allium sativum*) against chickpea wilt incited by *F. oxysporum f.sp. ciceris*, *T. viride* and *Allium sativum* bulb extract were the most suitable combinations, as important components of integrated management of chickpea wilt. Manjunatha et al., (2013) reported combination of *T. viride* and *P. fluorescens* to be effective against dry root rot of chickpea caused by *M. phaseolina*. Prasad et al., (2002) evaluated the potential of two antagonistic fungi viz., *T. harzianum* (PDBCTH 10) and *T. viride* (PDBCTV) and found them effective against wilt and wet root rot of chickpea. Efficacy of *T. harzianum* singly and in combination with chemicals like carbendazim and *Aspergillus niger* (Kalisena) was also reported (Poddar et al., 2004). Sharma et al., (1999) reported *T. harzianum* and *Absidia cylindrospora* as most effective in inhibiting mycelial growth of *S. sclerotiorum* causing stem rot in chickpea. Prasad and Rangeshwaran (2000) found modified wheat bran-kaolin granular formulation of *T. harzianum* to be effective against *R. solani* under field conditions.

Recently, several isolates of *Trichoderma* species were characterized and evaluated against different fungal pathogens of pulse crops (Dubey et al., 2007). One of each isolate of *T. viride*, *T. harzianum* and *T. virens* were selected for development of formulations and out of the several formulations developed, Pusa 5SD for seed treatment and Pusa biopellet for soil application were found to be the best in respect of their shelf life as well as efficacy (Dubey et al., 2009). These formulations alone and in combinations were proved highly effective against several diseases of pulse crops, namely, dry root rot of mungbean (Dubey et al., 2009), dry root rot of chickpea (Dubey et al., 2011b), wet root rot of mungbean and wet root rot of chickpea (Dubey et al., 2012) and wilt of chickpea (Dubey et al., 2013a). Pusa 5SD also found compatible with the most widely used insecticides like imidacloprid and thiamethoxam and an integrated module has been developed for the management of major diseases of mungbean (Dubey et al., 2013b).

**Application of BCAs in Cereals crop for management of plant disease:** Rice (*Oryza sativa* L) is the most widely cultivated food crop in the world, whose production is constrained by diseases of fungal, bacterial and viral origins. Species of *Trichoderma*, *T. harzianum*, *T. viride*, *T. reesei*, *T. longibrachitum* and *T. koningii* in combination with chemical control was evaluated by many researchers finding them effective against these diseases. Sheath blight of rice incited by *Rhizoctonia solani* is one of the common and destructive diseases of rice in India. There are several important reports on the biological management of this disease. Biocontrol agent combination study by Rao et al., (2013) *T. harzianum* and *Pseudomonas fluorescens* were found effective against brown leaf spot disease of paddy. The unleashed potential of *Trichoderma* was tested in management of rice diseases in
fields by several groups of researchers. Rice ecosystem requires study on the survival aspects and in this direction, soil and FYM (1:1) in combination was found supporting maximum growth of both fungal and bacterial antagonists tested (Gangwar and Sharma, 2013). Application of Trichoderma with pesticides has also been addressed by various workers. Chakravarthy et al., (2011) tested tolerance of 26 Trichoderma spp. isolates against pesticides and their antagonistic potential against R. solani and found T. reesei and T. longibrachiatum as most effective in inhibiting the growth of the sclerotial bodies. A study reported that the rice seed treated with two antagonistic fungi, viz., T. viride Tode (Harz) and T. harzianum Rifai along with chemicals were found effective to control sheath blight of rice and increase the yield of the crop (Das and Hazarika, 2000). In another study, T. viride was found an efficient agent to control the R. solani toxin activity against the same disease (Sriram et al., 2000). Khan and Sinha (2005; 2007) emphasized on the usefulness of T. harzianum and T. virens in foliar sprays and talc-based formulations for reducing disease incidence of sheath blight of rice. Maize (Zea mays L.) is another important cereal crop which suffers from soil borne and foliar pathogens. Some attempts have been made on the use of Trichoderma against important diseases of maize. Investigations made by Sankar and Sharma (2001) clearly indicated the performance of T. viride in in vitro and in vivo conditions which suppressed the charcoal rot disease caused by Macrophomia phaseolina and also enhanced the growth of crop. After a decade, Khedekar et al., (2010) evaluated the efficacy of T. harzianum against leaf blight caused by Helminthosporium turcicum and found similar results. In another set of experiments by Bhandari and Vishunavat (2013), efforts were made to test the efficacy of T. harzianum against ear rot of maize caused by Fusarium moniliforme where The strain showed 73.33% growth inhibition of F. moniliforme indicating it’s further use for in vivo trials. In another study by Pal et al., (2013) the potential of garlic and turmeric extracts, at 0.25%, 0.5%, concentrations and T. harzianum were exploited for enhancing the seed germination of maize indicating the importance of use of Trichoderma spp. for the enhancement of seed germination in various crops.

**Application of BCAs for abiotic stress management in crops:** Through biopesticides/BCAs are effective in controlling pest but sometimes in field efficacy is threatened due to extreme stress condition of environment. Fungal biopesticides require proper moisture contents to germinate their spore but in certain region where the atmospheric moisture is very low due to high temperature the fungal spore fail to germinate results in decrease in the efficiency of biocontrol agents (BCAs).This is a serious issue as the farmers are not aware of the fact which results in the decrease in the efficacy of the commercialized BCAs. There is a less acceptance of the BCA in commercial scale compared to chemical pesticides.

BCAs and Microbes are an integral component of agricultural ecosystems. Microbes colonizing the roots, rhizosphere, phyllosphere and spermosphere to organic relationships with plants and are capable of influencing their physiological process,
including tolerance to biotic and abiotic stresses. Besides influencing the physio-
chemical properties of rhizospheric soil through production of exo-polysaccharides and
formation of biofilm, microorganism can also influence higher plants response to abiotic
stresses like drought, chilling injury, salinity, metal toxicity and high temperature through
different mechanisms like induction of osmoprotectants and heat shock protein etc.in
plant cells (Fig.2). A good amount of information is available on the use of microbes
(Fungi and bacteria) for the management of biotic stresses such as disease and pest
(Harman et al., 2004).Trichoderma species are known to alter the response of plants to
abiotic stress. To alter the drought response includes drought avoidance through
morphological adaptation, drought tolerance through physiological and biochemical
adaptations and enhanced drought recovery. The root colonization by *Trichoderma*
increase the growth of roots and the entire plants, thereby increasing plant productivity
and the yield of reproductive organs.

![Fig.2: Mechanism of Biocontrol agents under abiotic stress condition in field](image)

Feedback received from several farmers, who have used *Trichoderma* for wheat seed
treatment, indicated that wheat crops raised from *Trichoderma* treated seeds tolerate
drought better than crops raised from non -treated or chemically treated seeds. This
could be due to better root growth and/or better availability of nutrients. Clearly, plants
are induced to operate more efficiently and to be better able to resist biotic and abiotic
stresses if their roots are colonized by effective Trichoderma strains. *Brassica juncea*
plants raised from *Trichoderma harzianum* isolates PB 9 or PB23 treated seed tolerated
water stress better than untreated plants or those treated with other isolates of *T. harzianum*. 
It is well documented that *T. harzianum* enhances root growth and helps in water absorption and nutrient uptake under osmotic stress (Harman *et al.*, 2004). When plants are under stress, the contents of reactive oxygen species may increase to toxic concentrations. Several studies have shown that root colonization by *T. harzianum* results in increased level of plant enzymes, including various peroxidases, chitinases, α-1-3-glucanases, lipoxygenase-pathway hydperoxide lyase and such changes in plant metabolism can lead to accumulation of compounds like phytoalexins and phenols (Harman, 2006). These compounds act as scavengers of ROS. Almost similar mechanism was involved in better germination of *T. harzianum* strain T-22 treated seeds of tomato exposed to biotic (osmotic, salinity, chilling or heat stress) or physiological (poor seed quality introduced by seed ageing) stress (Mastouri *et al.*, 2010). The consistent response to varying stresses suggests a common mechanism through which the plant-fungal association enhance tolerance to a wide range of abiotic and biotic stresses. A common factors that adversely affects plant under these stress conditions is the accumulation of toxic ROS resulting in increased concentration of lipid peroxidase. Treatment of seeds reduced accumulation of lipid peroxides in seedling to stress by scavenging ROS. *Trichoderma* strains enhance the activity of these pathways in part by enhanced expression of genes encoding the component enzymes (Mastouri, 2010; Mastouri *et al.*, 2010). Enhancement of these pathways in chloroplasts would increase photosynthetic efficiency by reducing damage by the superoxide anion and other reactive species involved in photosynthesis. At least part of the resistance and probably the increased photosynthetic efficiency is because the fungi improve the redox status of the plant.

Bacterial inoculates have been applied as biofertilizers that increase the effectiveness of phytoremediation. Recently studies have shown that some strain of PGPR can elicit tolerance of abiotic stresses. PGPR- induced physical and chemical changes in plants that results in enhanced tolerance to abiotic stresses such as drought, salt and nutrient excess or deficiency in termed as “induced systemic tolerance” (Yang *et al.*, 2009). Root colonizing non-pathogenic bacteria like *Pseudomonas* can provide “bioprotection” against biotic and abiotic stress and some root colonization bacteria increase tolerance against abiotic stresses such as drought, salinity and metal toxicity. Arbuscular Mycorrhizal (AM) symbiosis also increase the flexibility of host plants against salinity stress, perhaps with greater consistency than to drought stress and occurs widely in salt stressed environment. They help in alleviating the effect of salinity (Al Karaki *et al.*, 2001) by compensating nutritional imbalances imposed by salinization through improved nutrient acquisition, enhancing the ability of the plants to cope with salt stress, ion balance and improving plant nutrient uptake (Asghari *et al.*, 2005). Symbiotic stress tolerance involves activation of host stress response systems as soon as the plant is exposed to stress. This helps the plant in avoiding or adjusting the stress impact and synthesis of antistress chemicals by endophytic microbes (Miller, 2002).
References


Integration of mushroom cultivation in integrated farming system

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Farming in general and agriculture in particular has been the main stray of livelihood for rural population in India. India has been able to achieve food security through the use of improved technologies (high yielding varieties of agricultural, horticultural crops, improved breed of animals and poultry and adoption of advanced new generation technologies). In spite of having food security being achieved, the struggle for achieving nutritional security is still going on. Present day agriculture is facing issues of climate change and depleted cultivable land. The technologies which are sustainable, ecofriendly and climate resilient are to be a major part of future agriculture. With decreasing arable lands and effects of climate change, secondary agriculture holds a promising place to fill the voids of nutritional food security. Integrated farming system (IFS) remains a solution which can provide a sustainable livelihood to the farming community which is resource poor and prone to higher risks. IFS is the scientific integration and interaction of different interdependent and interacting farm enterprises for the efficient use of land, labour and other resources of a farm which provides year round income to the farmers specially located in the resource poor conditions (Roy et al., 2014). Intensive integrated farming system (IIFS) is a further improved approach where all the suitable agricultural, horticultural, agroforestry, animal science, poultry, fishery and natural resource conservation components are judiciously integrated so as to economize the space and time use efficiency in terms of overall production and productivity wherein the wastes of one component is used immediately in the other component of production system. Mushroom cultivation is one of the integral secondary agriculture components which are suited for integration in IFS. Mushrooms can help to address the problems of sustainability, nutritional security and management of agro-industrial wastes. Since mushroom cultivation does not require arable land, least affected by the climate change, it can provide lucrative employment opportunities to the rural youths, farm women and other farmers and have potential to supplement the farm income. Mushrooms are considered to be the most efficient and economically viable microbial technology which recycles agricultural residues into food and manure (Prakasam, 2012). Crop residues are converted to quality protein food which also contains minerals and compounds of medicinal values (Chiu and Moore, 2001; Prakasam, 2012). Mushroom cultivation is taken up under controlled conditions, has very less water requirement compared to the crops grown under field conditions, have short cropping cycle and are the highest protein producer per unit area and time.
MUSHROOMS FOR NUTRITIONAL SECURITY

Mushrooms are considered as next generation food because of unique nutritional contents. Mushrooms are rich in quality proteins, vitamins and fibre. Superior quality proteins (12-35% crude protein content) of mushrooms contain most of essential amino acids in good quantity (lysine, tryptophan, leucine, isoleucine, valine, threonine, tyrosine and phenylalanine). Fruiting body contains 80-90% moisture content, 26-82% carbohydrates and low fat contents. Mushrooms contain ergosterol that acts as a precursor for vitamin D synthesis, thus they are very good source of vitamin D. Mushrooms do not contain cholesterol. They are rich in dietary fibre (8-10%) and are an excellent source of vitamins and minerals. Among vitamins, mushrooms contain good quantity of vitamin B complex (thiamine, riboflavin and niacin) and vitamin C (ascorbic acid). They also contain folic acid and vitamin B12, which are not found in green vegetables. Most of the vitamins present in mushrooms are not lost after cooking. Among minerals, potassium, sodium and phosphorous are present in good quantity in the fruiting bodies of mushrooms, besides that traces of copper, zinc and magnesium are also present but lack iron and calcium. Mushrooms also have medicinal values. Various mushroom species are reported to have compounds responsible for curing many ailments.

Due to the absence of cholesterol and high amount of unsaturated fatty acids, mushrooms are the ideal food for heart patients. Taking *Agaricus bisporus* and *Lentinula edodes* lowers down the cholesterol level by 34 and 35 % respectively. Due to high potassium: sodium (K:Na) ratio, mushrooms are a good diet for hypertension patients. Low calorific value, absence of starch, low sugars and insignificant amount of fat makes mushrooms ideally suited for diabetic and obese persons. *Coprinus comatus* and *Pleurotus* spp. have anti diabetic effect. Some mushrooms put on clinical trial have shown to possess antiviral and anti cancer activities. Recent studies have indicated that all edible mushrooms especially button mushrooms have potential in preventing prostate and breast cancer. Alkaline nature and high fibre contents make mushrooms a suitable diet for the persons suffering from constipation and acidity problem. Keeping in view the nutritional and medicinal values of mushrooms, they have the potential of becoming next generation nutritious foods and can be of great use in nutriceuticals and pharmaceutical industries.

MUSHROOM CULTIVATION IN INDIA

Out of a dozen of widely cultivated mushrooms, button (*Agaricus bisporus*), oyster (*Pleurotus* spp.), paddy straw (*Volvariella volvacea*), milky (*Calocybe indica*) and shiitake (*Lentinula edodes*) mushrooms are the most commonly cultivated in India. Abundant of agricultural residues are produced every year in different agroclimatic zones of India. With the availability of improved strains of different mushroom species and production technology in hands, it is now possible to undertake year round cultivation of mushrooms in different agro-climatic zones. Around 600 million tonnnes of agricultural residues are
produced every year in India, out of which only 0.04% is currently used in mushroom production (85% button mushroom and remaining 15% for other species of mushroom) (Prakasam, 2012). If we could even use 1% of these agricultural byproducts, 3.0 million tons of mushrooms can be produced. So here lies the opportunity for taking up mushroom cultivation on large scale and possibility of its integration in every farming system module. With respect to North East (NE) India, mushrooms are the food items which are relished by the people of this region since time immemorial. This region is characterized by CDR system which means it is complex, diversified and risk prone. Hence adoption of suitable IFS can sustain the overall agricultural production, productivity, maintain soil and environmental health while maximizing the overall financial output for the farmers. In the IFS system mushroom cultivation has to be an integral component wherein the farm byproducts can efficiently be converted to nutritious foods (mushrooms) and thus increasing the income of the farmers.

At present in India, around 1.2 lakh tons of mushrooms are produced every year. With increasing health concerns demand for fresh and processed mushrooms is increasing every year. Hence there a large scope of mushroom cultivation and its integration with the crop based or animal based farming systems. There is a large scope of mushroom cultivation in NE region. Different academic institutions like ICAR Research Complex for North Eastern Hill Region (ICAR-RC-NEH) and its regional centres in different NEH states; Directorate of Mushroom Research, Solan; Krishi Vigyan Kendras; State Agricultural and Horticultural departments, Central Agricultural University; other public institutions and Non-governmental organizations are working for the popularization of mushroom cultivation in NEH region. Since last four decades ICAR-RC-NEH has undertaken systematic research on standardization of mushroom cultivation technology in NEH region its dissemination to the farmers of region.

**MUSHROOM CULTIVATION TECHNOLOGY**

The basic requirements of mushroom cultivation are discussed in the following sections:

**Mushroom Spawn**

Spawn is basically the ‘seed’ of mushroom which is used for its cultivation. Spawn consists of mycelia of the fungus multiplied on suitable substrates like cereal grains. Like in other crops, seed or spawn is the key input in mushroom cultivation. Availability of quality spawn is major issue in successful mushroom production. A good quality spawn leads to high yield potential, absence of contaminations and finally high economic benefits. Spawn production requires special technical skill and a laboratory for quality and economic spawn production (Borah et al. 2010).

**Spawn Production of Mushroom**

Spawn production is taken under aseptic conditions. For this a dedicated mushroom spawn production laboratory is required. The basic infrastructure and state of art facilities required for a spawn production laboratory are as follows:
**Compulsory Equipments and Consumables**

1. Laminar Air Flow
2. Autoclave
3. BOD Incubator
4. Lab Refrigerator
5. LPG Gas Stove
6. Hot Air Oven
7. Weighing Balance
8. Racks
9. Glass wares and plastic wares, polypropylene bags, PVC rings etc.
10. Need based equipments/instruments (utensils etc.)
11. Cereal grains, calcium sulphate and calcium carbonate

**Optional (for mechanized spawn production laboratory)**

Mushroom spawn production machinery (motorized grain cleaner, Boiled Grain and Chalk Powder Mixer, Bag Filling Machine, Bulk Spawn Incubator etc.).

**Approximate expenditure**

Approximate expenditure for establishment of a spawn production laboratory, excluding the cost of the building construction, electrification, and water supply for producing 10 tonnes spawn per annum are as follows:

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Item Nos.</th>
<th>Approx. cost (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Fixed cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Autoclave</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Laminar flow</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Refrigerator</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>BOD incubator</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Gas stove</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Weighing balance</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Racks</td>
<td>50,000</td>
</tr>
<tr>
<td>9</td>
<td>Hot air oven</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Glass wares and plastic wares</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>Need based equipments/instruments (utensils etc.)</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B. Recurring cost

a. Raw materials

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Item Nos.</th>
<th>Approx. cost (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>80q grains @ Rs. 1000/q (approx. 1.4 kg spawn/kg paddy grains and 5% contamination)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Calcium carbonate (1.5q) @ Rs. 5000/q</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Cotton 2q @ Rs. 6000/q</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Rubber bands 30 pkts @ Rs. 250/pkt</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1q polypropylene bags @ Rs. 1500/q</td>
<td></td>
</tr>
</tbody>
</table>

164
6. Readymade PDA and OMA media 1kg each  
8. Energy consumption/year  
9. Miscellaneous/Need based (disinfectant, gloves etc.)

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Quantity/Unit</th>
<th>Cost (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Readymade PDA and OMA media 1kg each</td>
<td></td>
<td>30,000</td>
</tr>
<tr>
<td>Energy consumption/year</td>
<td></td>
<td>1,00,000</td>
</tr>
<tr>
<td>Miscellaneous/Need based (disinfectant, gloves etc.)</td>
<td></td>
<td>50,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>3,02,000</td>
</tr>
</tbody>
</table>

b. Salary

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity/Unit</th>
<th>Cost (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Assistant @ Rs. 8000/- month/person</td>
<td>1</td>
<td>96000</td>
</tr>
<tr>
<td>Labour @ Rs. 3000/- month/person</td>
<td>2</td>
<td>72,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>1,68,000</td>
</tr>
</tbody>
</table>

C. Interest and depreciation

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>On equipment and instrument (Rs. 6,67,000) (10% depreciation and 10% interest)</td>
<td>98,400</td>
</tr>
<tr>
<td>Income from sale of 10 tonnes spawn @ Rs. 75/kg</td>
<td>7,50,000</td>
</tr>
<tr>
<td><strong>Net profit per year</strong> (750000-568400)</td>
<td><strong>1,81,600</strong></td>
</tr>
</tbody>
</table>

Procedure for the Production of Mother Spawn

Spawn can be prepared on any kind of grains like paddy, wheat, jawar, bajra, rye etc. The paddy grains are commonly used for spawn production under NE conditions. These should be free from diseases, should not be broken, old and free from damage by insect-pests. Step-wise procedure is mentioned below:

1. Wash the paddy grains thoroughly in sufficient water three to four times.
2. Soak the washed grains in sufficient water and boil in a container for 15-20 minutes (ensure that grains are boiled fully but are not burst).
3. Remove the excess water by spreading the boiled grains on sieve.
4. Either leave the grains as such on sieve or keep them under shade for 4 hours so that they get dry.
5. Mix the grains with gypsum (calcium sulphate @ 2%) and chalk powder (calcium carbonate @ 0.5%) so that the pH is maintained to around 7-7.8 and to avoid the clumping of the grains. Use 20 grams of gypsum and 5 grams of chalk powder for 1 kg of the paddy seeds used (on dry weight basis). First mixes the required quantity of gypsum and chalk powder separately and then thoroughly mix it with the grains.
6. Fill around 300 grams of above prepared substrate (boiled grains mixed with gypsum and chalk) in glucose/milk/glass bottles with 2/3rd volume filled. Plug these bottles with non-absorbent cotton. Cover these plugs with aluminium foil.
7. Autoclave the substrate filled bottles at 22 p.s.i pressure for 1.5-2 hours.
8. After autoclaving leave the bottles in the room for 24 hours for cooling.
9. Keep these bottles in laminar air flow chamber under UV light for 20-30 minutes before the inoculation.
10. Inoculate a piece of pure culture growing mycelium from Petri plate or slant to these bottles under aseptic conditions in the laminar air flow chamber.
11. Incubate these inoculated bottles in BOD incubator at 25° C for 20-25 days. Shake the bottles gently after every 5 days for even distribution of inoculum.

12. In around 2-3 weeks the mushroom mycelium fully colonizes the spawn grains. This spawn prepared from the pure culture is called as mother spawn, which is further used to produce commercial spawn for cultivation of mushrooms.

**Procedure for the Production of Commercial Spawn or Spawn for Cultivation**

This spawn is most commonly prepared in heat resistant polypropylene bags which have double sealing at the bottom. The ideal size of bags for half kg of spawn is 35 x 17.5 cm and for one kg of spawn is 40 x 20 cm. Step-wise procedures is mentioned below:

1. Fill the grains in polypropylene bags.
2. Place polypropylene neck ring (height 2 cm and diameter 4 cm) near the top by passing the upper open end of bag through this ring. Then fold back the bag and plug it with non-absorbent cotton.
3. Sterilize these bags at 22 p.s.i pressure for 1.5-2 hours.
4. After these bags get cool, shake them well before inoculation so that the water droplets accumulated inside the bag are well absorbed by the grains.
5. Put these bags under UV for 20-30 minutes in laminar air flow chamber before inoculation.
6. Under aseptic conditions in the laminar airflow chamber inoculate 10-15 grams of mother spawn per bag. (If the small scale cultivation has to be taken up, then the mycelium of mushroom growing on slants can also be directly inoculated in these autoclaved bags).
7. Shake the inoculated bags well.
8. Incubate in BOD incubator at 25° C for 15-20 days.
9. Regularly examine the bags for contamination during the incubation. The contaminated bags once observed should be immediately discarded.
10. When the mycelial run is complete the bag becomes white.
11. These bags can then be store at 4° C for future use. These can be stored up to one month or maximum two months

**Cultivation of mushroom**

Many cultivated species of mushroom are available which can be selected for growing in the different climatic conditions prevailing throughout the country according to the climatic requirements and availability of raw materials. In India the mushroom varieties viz. button mushroom (*Agaricus* spp.), oyster mushroom (*Pleurotus* spp.), milky mushroom (*Calocybe indica*) and paddy straw mushroom (*Volvariella volvacea*) are commonly cultivated in a small scale to commercial basis throughout the year (Thakur, 2014). The production of tropical mushrooms like oyster (*Pleurotus* spp.), paddy straw mushroom (*Volvariella volvacea*), milky mushroom (*Calocybe indica*), black ear
mushroom (*Auricularia* spp.) and reishi mushroom (*Ganoderma lucidum*) utilizing locally available substrates viz., paddy straw, wheat, soybean, cotton wastes, coffee waste, water hyacinth, tree saw dust, sugar cane bagasse, wild grasses and various categories of refuse and lignocellulosic wastes have great potential to exploit and convert it in to a highly nutritious food in less time per unit area (Singh, 2011).

Oyster Mushroom (*Pleurotus* sp.) is the third largest cultivated mushrooms. Under the Indian conditions, especially in North Eastern part, oyster mushroom has the wide scope for cultivation due its easy cultivation technology and availability of wide range of *Pleurotus* species which can be grown under the specific temperature regimes of the region. This mushroom naturally grows in the tropical and temperate forests on dead, decaying wood logs and decaying organic matter. Oyster mushroom can be grown on any kind of agricultural or forest wastes which contains lignin and hemicellulose. It does not require controlled environmental conditions for cultivation. Because of the cheap and easily available raw materials needed and congenial climatic conditions in NE India, it is mushroom species of choice for cultivation. Its cultivation has great potential under IFS conditions to generate a profitable source of income to the resource poor farmers.

**Cultivation Technology of Oyster Mushrooms**

The different steps involved in the cultivation of Oysters mushroom are:

**Preparation of substrate**

Oyster mushroom can be grown on a variety of agro-industrial by-products which have high contents of cellulose, lignin and hemicellulose. The substrate should be fresh, dry free from the mould infestations and properly stored. It is recommended that substrate which is harvested immature, having green chlorophyll patches should not be used. A variety of substrates such as wheat straw, paddy straw, ragi straw, stalk and leaves of maize, jawar, bajra and cotton, sugarcane bagasse, wastes of jute and cotton, peanut shells, dried grasses, used tea leaf waste etc. can be used for Oyster cultivation.

**Steps in Substrate Preparation:**

1. First chop the selected straw into small pieces of the size 5-10 cm
2. Pasteurize this straw by either of the following method:

   **Hot water treatment:** Soak the straw into hot water (85° C) for 30-45 minutes. Then drain the excess water and let the straw cool down by spreading on a sterile surface.

   **Chemical method:** Take 90 litres of water in rust proof drum or tub. Slowly steep the straw into water. In another plastic bucket prepare a solution of carbendazim 50WP @ 7.5 grams and formaldehyde @ 125 ml by mixing them well. Now slowly pour this solution in already soaked straw. Press the straw and cover it with polythene sheet. After 15-18 hours take out the straw and drain out the excess water. Spread the straw on sterile surface to evaporate the excess water.
As per the latest recommendations, the chemical pasteurization of substrate is discouraged and only hot water treatment has been recommended for the substrate pasteurization (Proceedings of XVII Annual Group Meeting of Research Workers, 2015, Directorate of Mushroom Research, Solan).

3. **Spawning:** Spawning should be done in a room which was earlier fumigated with 2% formaldehyde for 48 hours. If spawning is done outside, then the surface of tarpoline sheet as well as hands should be sterilized with spirit or alcohol.

4. Then mix the spawn thoroughly or in layers while putting the straw into polypropylene bags (60 x 45 cm, 125-150 gauze thickness). 300 grams of spawn grain is sufficient for 10-12 kg of wet substrate. Around 10-15 small holes should be made on all the sides of polypropylene bags with the help of pin.

5. Keep these bags in incubation room for mycelial run. Bags can be kept on raised platforms or shelves or hanged with the roof. Optimum temperature for growth is 22-26° C.

6. Once the mycelial run is over i.e. the bags have become white due to the growth of mushroom mycelium, make some holes at several places in the bag so that the fruiting bodies can grow out.

7. During fruiting maintain the relative humidity of 75-85% by spraying water on the gunny bags or sand spread on the floor. One or two spraying of water daily is sufficient. There should be 8-12 hours of light during fruiting.

8. Harvest the mushrooms before water spray. Harvest by gently twisting the fruiting body.

9. After first harvesting keep the bags in growing chamber so that other mycelium can grow and produce more fruiting bodies which can then be again harvested.

10. Pack the fresh mushrooms in perforated polythene bags for marketing.

11. In a period of one and half month to two months, 500-700 kg of fresh mushroom can be harvested from 1 ton of paddy straw.

**Economics of Oyster mushroom production**

<table>
<thead>
<tr>
<th><strong>A. Fixed Capital (Rs.)</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mushroom cropping room (thatched roof) of 3m x 6m size with a capacity to hold 250 beds at a time</td>
<td>25,000.00</td>
</tr>
<tr>
<td>2. Chaff cutter</td>
<td>7,000.00</td>
</tr>
<tr>
<td>3. Aluminum sauce pan for boiling of straw (120 litres capacity)</td>
<td>2,500.00</td>
</tr>
<tr>
<td>4. Sprayer one</td>
<td>300.00</td>
</tr>
<tr>
<td>5. Fire wood</td>
<td>1000.00</td>
</tr>
<tr>
<td><strong>Sub Total</strong></td>
<td><strong>35,800.00</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>B. Fixed cost (Rs.)</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Interest @ 10% for crop season (4 months)</td>
<td>3580.00</td>
</tr>
</tbody>
</table>
2. Depreciation on items 1 – 5 @10% : 3580.00

Sub Total : 7,160.00

C. Working capital (Rs.)
1. Paddy straw 0.5 ton (500 kg) : 2,500.00
2. Spawn 150 packets of 200 g each @ 20/- : 3,000.00
3. Polythene bags (10 kg) : 1,500.00
4. Labour, 100 man days @ 150/- : 15,000.00
5. Miscellaneous : 500.00

Sub Total : 22,500.00

D. Cost of mushroom production (Rs.)
1. Working capital plus fixed cost ( B + C ) : 29,660.00
2. Cost of production of 1 kg mushroom (29,660/500) : 59.32

Sub Total : 30,340.00

E. Income (Rs.)
1. By sale of 5 kg mushroom/day @ 150/ per kg. for 100 days : 60,000.00
2. Total cost of production : 29,660.00
3. Net Income out of 4 months : 30,340.00

POST HARVEST PROCESSING OF MUSHROOMS

As the fresh mushrooms have more than 90% moisture content, they have very short shelf life. The high water content of mushrooms also becomes conducive for multiplication of various microbes which cause rot of the harvested fresh mushrooms. Metabolic activities continue even after harvest and fruit bodies get wither due to the loss of water content. Therefore, harvested mushrooms cannot be kept fresh for longer periods. However, it can be stored for certain time period by adopting some preservation procedures. The methods of preservation developed for mushrooms can be grouped in to two types, they are:

1. Short term preservation (can be stored for maximum period of 10-15 days)
   i) Room temperature: Keeping in room temperature of around 30-33 °C, the mushrooms remain fresh for 8-12 hours only whereas it is possible for 24-36 hours during winter at lower temperatures.
   ii) Refrigeration: Fresh mushrooms can be stored for 7-15 days in a refrigerator depending on the type of package and storage temperature.
   iii) Brine solution preservation: In a solution of common salt (in water) in high concentration (10-15%), fresh mushrooms can be kept safe for 6-7 days.
   iv) Other methods: Lactic acid fermentation and gamma irradiation. These are tedious, costly and sometimes risky also.

2. Long term preservation
   i) Sun drying: Fresh mushrooms after sorting and selection (trim off the hard stalk portions), are thinly spread on a sieve and sun dried for 3-5 days. To avoid browning
of the fruit bodies, a shade may be provided to the mushrooms by spreading a black cloth at about 1 foot above the sieve. This type of dry mushrooms can be kept in air tight containers up to 5-6 months.

ii) **Machine drying**: In machine drying method, fresh mushrooms are dried in electrically operated drier within 6-8 hours. It is a costly method.

iii) **Blanching**: Sorted out mushrooms are steeped in warm water of 80-85°C for 1-2 min. only and then sun dried. Sometimes sodium chloride @ 400 ppm and citric acid @ 0.1-0.2% may be added to the water before boiling to retain or improve the natural colour.

iv) **Other methods**: Freeze drying, canning, pickling etc.

Fresh mushrooms can also be processed and value added products like various mushroom culinary, soup powder etc. can be prepared. Mushrooms can also be canned to meet the demand in the off season.

**MANAGEMENT OF SPENT MUSHROOM SUBSTRATE**

Once the mushroom crop is harvested, the mushroom beds become exhausted and the substrates are considered ‘spent’ or ‘used mushroom substrate’. If not handled properly, the ‘spent mushroom substrate’ creates various environmental problems including ground water contamination and nuisance by being the safe home for pathogens. The diversified uses of ‘spent mushroom substrate’ in managing agriculture, environment and recycling energy have come to light recently.

i) The used mushroom beds can be broken into pieces and applied in vegetable or flower garden as organic manure.

ii) Spent mushroom substrate is a better substrate for vermicompost. Usually 100 kg of spent mushroom substrates yield 50 kg vermicompost. The nutrients contents of the vermicompost prepared from spent mushroom substrates are Nitrogen (1.85%), Phosphorus (0.90%) and Potash (1.12%) (Ahlawat and Tewari, 2007).

iii) The spent oyster mushroom substrates serve as good livestock feed especially for goats, cattle and pig because the oyster mushrooms have the capability of reducing the organic carbon and increasing the nitrogen content of plant residues. Cattle prefer these when the spent bed is broken in to pieces, boiled with other feed and salt.

**MARKETING OF MUSHROOMS**

Marketing of mushrooms in India is not organized to a larger extent. It is a simple system where the producers directly sell the product to retailers or consumers. Per capita consumption of mushroom in India is 40 g as compared to over a kg in many countries (Netherlands: 11.62 kg followed by Ireland: 6.16 kg). Systematic efforts to strengthen and expand the market are required to be taken up. With mushrooms being recognized as functional food, their trade has gained a momentum in the recent years. India is
exporting mushrooms to American, European and other countries. Organized assistance for mushroom marketing is lacking in India. Export oriented mushroom production units have their own individual arrangements for marketing. Mushrooms are exported as canned (in large containers of 3-5 litres) or in preserved form in brine solution. Lower production cost, higher productivity if supplemented with processing backup, Indian mushroom industry can become globally competitive.

In India itself a large market exists for the mushrooms, which can be further expanded by vigorous market oriented extension activities. Like China where 80% of the produced mushrooms are consumed domestically, we also have to increase domestic market. Since fresh mushrooms have very short shelf life, processing of the fresh produce is required for realizing the good economic benefits. Around 75% of button mushroom production comes during the 2-3 winter months (Dec-Feb), and due to over-saturation of market during these months, producers are forced to sell their produce at lower prices. Thus these can be processed and canned for selling during off-seasons. Oyster mushroom are not produced in that much large quantities, thus as such there is no problem in selling them as fresh. However, the market for dried oyster faces some challenges, as individual farms are not able to meet the export orders which are of large quantity. If producers form cooperatives, they may meet the big export order by pooling their products.

In North Eastern region of India, where very small fragmented mushroom farms exists, marketing to outside markets and to other countries is a problem. We have proposed a system of mushroom production and marketing where a large group of farmers are brought into cooperative mode. Some of them are trained in spawn production technology, who will then take up the production of quality spawn at their farm for the other larger group of producers. This producer group takes up the cultivation of mushrooms at their individual farm and then pools the whole produce for marketing. Another group of rural youths who are educated are engaged in marketing who arrange for the selling the pooled mushroom produce in local market, markets in other parts of India as well as for export purpose. This system will be very effective in those small mushroom farms which are taken as integration with IFS and where the total produce is small.

**CONCLUSION**

Mushrooms cultivation is a technology which can easily be integrated in farming system. In addition to provide economic benefits, it can help combating the protein deficiency, thus providing nutritional security. With the cultivation technology available for a number of mushroom species which can be cultivated under wide range of agro-ecological situations, it is now possible to undertake mushroom cultivation throughout the year. Mushroom production is a profitable venture, which does not require any significant capital investment or arable land and can be grown on agricultural waste substrate. Integrated farming system is becoming a preferable farming module under different agro-ecological situations. The major aim in IFS is to utilize space and time in
most efficient manner so as that nothing remains as waste and each byproduct is being utilized as input in other cultivation system. The byproducts of agriculture and animal husbandry components can be efficiently utilized for the production of mushrooms, thus adding to total farm income. As a livelihood diversification option, mushroom cultivation has enormous potential to improve food security and income generation being fast yielding and nutritious food with great medicinal value. Mushroom cultivation can be taken up with low inputs, on a part time basis, requires little maintenance and is a viable and attractive activity for rural women, unemployed youth and other farmers. In future, for making this enterprise more economic and beneficial; establishment of spawn production units in public and private sector and their monitoring to provide the quality spawn, involvement of cooperative and other marketing organizations for providing inputs and suitable marketing system, availability of technical guidance and financial support to the small scale and export oriented mushroom industries will be required.

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Fish based integrated farming system in era of climate variability

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Introduction:

Water is emerging as international challenge and its most efficient management as well as recycling has been given high priority by almost all countries. Twelve percent of pesticides sold worldwide are applied to rice crops, and no other single crop accounts for as much pesticide use.

India is the second largest producer of fish in the world contributing about 5.5 per cent of global fish production. India is also a major producer of fish through aquaculture and ranks second in the world after China. The total fish production achieved during 2011-12 is at 8.67 million metric tonnes and the contribution of fish from inland sector alone is at 5.29 million metric tonnes which is about 61% of overall fish production.

Fish provides nutritious food, fishery and fish farming generate income and employment to millions of poor people and trade in fishery products contributes to poverty reduction and national economic growth in many developing countries. Global fish production from capture has remained relatively stable over the past two decades while fish production through aquaculture has progressively increased. Indian aquaculture has demonstrated a six and half fold growth over the last two decades, with freshwater aquaculture contributing over 95 percent of the total aquaculture production. The culture systems adopted in the country vary greatly depending on the input available in any particular region as well as on the investment capabilities of the farmer. While extensive aquaculture is carried out in comparatively large water bodies with stocking of the fish seed as the only input beyond utilising natural productivity, elements of fertilisation and feeding have been introduced into semi-intensive culture.

Integrated Fish Farming is one of the best examples of mixed farming in the era of climate variability. This type of farming practices in different forms mostly in the East and South East Asian countries is one of the important ecological balanced sustainable technologies. The technology involves a combination of fish polyculture integrated with crop or livestock production. On farm waste recycling, an important component of Integrated fish farming, is highly advantageous to the farmers as it improves the economy of production and decreases the adverse environmental impact of farming. Small farmers in developing countries are poorer than the rest of the population, often not getting enough food to lead normal, healthy and active lives. Dealing with poverty and hunger in much of the world, therefore, means confronting the problems that small farmers and their families face in their daily struggle for survival. One option for economically and ecologically sustainable development of farming systems is the integration of agriculture and aquaculture. Integrated fish farming serves as a model of sustainable food production by following certain principles.

Principles:

- The waste products of one biological system serve as nutrients for a second biological system.
• The integration of fish and plants results in a polyculture that increases diversity and yields multiple products.
• Water is re-used through biological filtration and recirculation. Local food production provides access to healthy foods and enhances the local economy.

Benefits of integrating fish with crop are:
• Conservation of water resources and plant nutrients.
• Intensive production of fish protein.
• Reduced operating costs relative to either system in isolation.

Selection criteria for fish species:
• Fast growth rate.
• Good food conversion efficiency.
• Acceptability of supplementary and natural food.
• Adaptability to crowded conditions and resistance to diseases.
• Ability to withstand changing physico-chemical and biological conditions of the pond/trench and paddy plot water.

Rice –Fish Farming:
Generally, fish culture in paddy fields is undertaken as second crop after the single annual crop of paddy or as an intermediate crop between the paddy harvest and the next transplantation or as concurrent crop with paddy. This system of farming is most prevalent in Japan, China, Indonesia, India, Thailand and Philippines involving mainly common carp, silver carp, bighead, Puntius, tilapia, snakehead, Trichogaster, Helostoma, Osteochilus, gourami in freshwater and shrimp and milk fish in brackishwater.

Rice is the major crop and staple food for over 1.6 billion people of the world. Over 90% of the rice is produced in Asian countries, and it is the sole livelihood of most rural farmers. Collection of wild and naturally occurring fish from paddy fields has been an age-old practice as the rice cultivation by itself. In fact, the practice of incorporation of fish in rice fields was introduced in Southeast Asian countries from India about 1,500 years ago. Planned rice-fish system ensures higher productivity, farm income and employment in these areas. The systems are highly relevant to poor people and having limited size farm.

In certain areas, paddy fields remain flooded with water for a period of 3-8 months in a year, during which some growth of fish is easily possible. Hence, fish is cultivated in paddy field to give sustainable additional supply to the farmer. In India various techniques are employed for fish culture in paddy fields depending upon the climate local conditions, species of fish available and the variety of paddy cultivated. The cultivation of paddy is the primary purpose of farmer; hence fish culture is to be adapted to the schedule of paddy cultivation. Species that are suitable for culture in paddy fields must be able to thrive in shallow water. They should be able to tolerate relatively higher temperature and turbidity. Certain carps, murrels and tilapia are suitable for culture in paddy fields. Fish culture is beneficial to the paddy also to some extent. Fish perform tillage; destroy weed and insect that cause damage to the paddy plants, thus increasing paddy production. Fish controls the excessive growth of plankton, which compete with
the paddy, also control zootecton, insects, molluscs, the submerged and floating weeds
habouring the above and adversely affecting paddy. Fish fertilize through its fecal matter
and acts as “swimming fertilizer factory” and also overturns the submerged soil normally
under reduced stage making thus available more nutrient and oxygen to the root of
paddy, acting like a biological plough (Sinha, 1985).

In fact, in integrated farming nothing is wasted, the by-product of one system becomes
the input for other. The pond embankment-used for terrestrial crop and raising of the
livestock near the water bodies offer integration of such farming system with fish
cultivation. The recent approach to feed the stocked fish with supplementary feeds and
also to enrich the water with organic and inorganic fertilizers to augment fish production
and utilization of the enriched pond mud and water for crop farming necessitates an
integration of fish culture with other farming systems.

In order to facilitate fish culture in paddy-fields, the farmers make water retention or
detention structures which help storage and conservation of water favouring paddy
growth. These structures are either circular moat-like trench, pond or ditch type
depending on the configuration/topography of the land. The use of such improvisations
of paddy fields fall under three broad categories: (i) for harvesting the wild (natural
occurring fish crop); (ii) for harvesting the fish crop after certain interval of time i.e.
trapping and holding for growth; and (iii) for raising fry to fingerlings or to marketable
size fish. Generally, fish culture in paddy fields is undertaken as second crop after the
single annual crop of paddy or as an intermediate crop between the paddy harvest and
the next transplantation or as concurrent crop with paddy. This system of farming is most
prevalent in Japan, China, Indonesia, India, Thailand and Philippines involving mainly
common carp, silver carp, bighead, Puntius, tilapia, snakehead, Trichogaster, Helostoma,
Osteochilus, gourami in freshwater and shrimp and milk fish in brackishwater.

In India, this farming is practised in the states of Bihar, West Bengal, Orissa and Assam
where enough water is present in the paddy fields. The paddy fields retain water for 3-8
months in a year. The interest in this practice has declined in recent years due to the use
of pesticides to protect high yielding varieties of paddy.

This practice can be done in following types of paddy plots-

i) Perimeter type- paddy grows in the middle.

ii) Central pond type — paddy growing area is on the perimeter.

iii) Lateral trench system- trenches are provided on either one or both sides of the
moderately sloping field.

The variety of rice used in this culture is Panidhan, Jalmagna, CR26077, Tulsi etc. while
the fish spp. are Indian major carps, *Channa spp*, *Oreochromis mossambicus*, *Clarias
batrachus*, *Anabas testudineus*, silver carp, grass carp, common carp. The total
production in such practice is approximately 90 quintal from 2 paddy crops while the fish
production is about 1000 kg from 1 ha.
Rice-Fish Farming in Ziro valley, Arunachal Pradesh, India:

Agriculture has been the mainstay of livelihood for the Apatanis. Paddy cum fish culture practiced by the Apatanis in the Ziro valley of Arunachal Pradesh is unique system integrated hill agriculture. UNESCO has, therefore, proposed Ziro valley as a World Heritage Site for it’s for its ancient custom, forming the basis of the eco-preservation efforts.

The Ziro valley surrounded by gentle slopes of mountain ridges all around with moderate sunshine and rainfall of 6050mm is paradise for wet rice cultivation. Starting from land preparation till the harvest of paddy and fish this unique system has scientific background.

- The people categorise their fields as zebi aji (soft field) and aller aji (hard field).
- Generally in soft fields the pyapin (Oryza sativa) variety of paddy is grown and lesser numbers of common carp are reared for once in a year.
- Due to the softness of the field, there is a risk of roots being damaged by fish. Hence, only one batch of paddy and fish are reared.
- In hard fields, two batches of fish are reared in a crop season. The first batch of fish is stocked during late March to early April before the transplantation of paddy saplings. These fishes are harvested in mid June and second batch is put in the month of July which is harvested in the month of September.
- The average weight attained by the fingerlings at the time of harvest ranges from 130 to 400 g.
- Based on the conservative estimates of village elders a hectare of land on an average yields about 200 kg of fish.
- The excellent efficiency of the fish production is despite high mortality of fingerlings. The fishes form an important part of diet of the Apatanis and fetches them subsidiary income with low inputs. Paddy-fish systems help poor and small farmers having too small holding for crop production.
- Increase cash income, improve quality and quantity of food produced and exploitation of unutilised resources.

The preparation of paddy fields for paddy cum fish culture starts in the month of October which involves removal of mud from the channels which will be used to drain out excess water from the field during the cropping season. At the same time rice husk, waste product of local beer, animal excreta, poultry droppings, household waste and burnt paddy straw are applied in the field as organic manure which later serves as feed for fish too. Though, the climate of Ziro valley remains cold during the month of January, the preweeding and preparation of nursery, preparation of bundhs starts during this month. All these works are carried out by community participation.

In this system, local verities of paddy known as Gyaremipia, Gyatemipia and Gyapemipia are cultivated. During the month of January nursery beds are prepared for their seedlings. The seeds are sown in the month of February immediately after the preparation of nursery. During the month of February, the community works together to clean the weeds from the field and bundhs. Generally the paddy plots measure from 40m x 40 m to 50m x 50m. Besides bundhs of paddy field are renovated or constructed and
maintained at a minimum height of 12 inches and maximum of 18 inches and it is ensured that during the rainy season the paddy field is not flooded.

After the field preparations, water is released into the field. In the month of April, transplantation of paddy starts. Generally, nursery beds are located near the main field for easy transportation. By now the seedlings of nursery beds attains a length of 7-10 inches. Healthy and disease free seedlings are carefully selected and uprooted from the nursery beds for transplantation to the main paddy field. Transplantation is done by maintaining the required plant to plant space. The normal plant to plant space is approximately 6-7 inches. After a month re-transplantation is done to replace the dead seedlings.

In Ziro valley, only Common Carp (Cyprinus carpio) is cultured with paddy. Three verities of Common carp namely Scale carp, Mirror carp and Leather carp are cultured. The fish fingerlings are released in the paddy fields during the month of March –April. In a 40m x 40m paddy plot 1000 numbers of Common Carp fingerlings are generally released. Just after the release of the fish fingerlings the water inlet and outlet pipes are blocked to protect the fingerlings from being swept away. Monsoon starts in the month of June and weeding after transplantation is done during this period. Farmers constantly monitor the water level of the paddy fields during monsoon to ensure that the paddy is not over flooded or the fishes are not swept away to the next paddy field.

June and July are the busiest months for the Apatani farmers. After the weeding of the paddy fields the farmers go for harvesting of the fishes during this period. Special kinds of net baskets are used to catch the fishes from the paddy field. Before the harvesting the fishes, water is drained out so that the fishes accumulate only in the channels of the field which helps in catching the fishes. The farmers only harvested the bigger fishes which have market value and the smaller ones are released back into the field so as to allow them to grow for the next harvesting which continue up to August last part. During these months Common Carp attains a weight of around 300- 500 gms. From a plot of 40m X 40m, during this period around 120- 130 kg of Common Carp can be harvested. During the peak season, these fishes fetch an average rate of Rs. 70- 80 per Kg in the local market. The paddy crop is harvested from mid part of September till October.

**Relevance of Integrated Livestock-Fish Farming**

- Meat as well as fish production in NEH region is inadequate
- Majority of the population live in rural areas and may be undernourished
- Aquaculture in NEH region is mainly based on pond culture and seasonal village tank culture
- Intensive farming of livestock produce large quantities of manure and animal waste which needs to be disposed in order to prevent serious environmental problems.
- This animal excreta or manure can be effectively utilized in fish production
- 4 – 5 kg of organic manure can be converted into 1 kg of fish
- In NE states, almost all the household have livestock component and if the farmer has pond for fish culture, integration of fishery with livestock is a viable option.

Asia is also perceived as the ‘home’ of aquaculture, as aquaculture has a long history in several areas of the region and knowledge of traditional systems is most widespread.
Furthermore, the integration of livestock and fish production is best established in Asia. Integrated farming is commonly and narrowly equated with the direct use of fresh livestock manure in fish culture (Little and Edwards, 1999). The term ‘integrated farming’ is broadly used for integrated resource management.

Benefits of integration are synergistic rather than additive; and the fish and livestock components may benefit to varying degrees.

Benefits of animal manures in pond culture: [Source: Modified after Knud Hansen (1998)]

- It is a good source of N, P and C, the latter may be limiting in rain-fed or other ponds with low alkalinites
- Can provide a substrate for zooplankton production
- Can assist in clarification of clay turbidity in pond water
- Can reduce the rate of P adsorption into pond sediments if present as a layer at the sediment-water interface
- Can reduce seepage of pond water
- Can act as direct feed, especially for detritivorous fish

Integration with livestock:

The integration between livestock and fish production concern use of nutrients, particularly reuse of livestock manures for fish production. The term nutrients mainly refers to elements such as nitrogen (N) and phosphorus (P) which function as fertilizers to stimulate natural food webs rather than conventional livestock nutrition usage such as feed ingredients, although solid slaughterhouse wastes fed to carnivorous fish fall into the latter category. There are also implications for use of other resources such as capital, labour, space and water. A variety of factors affect potential linkages between livestock and fish production.

Livestock-fish systems in which waste from animals continuously raised in a pen and fed complete feeds ('feedlot') are used as pond fertilizers are the most common type of integrated system outside China (Edwards, 1993). Since fish production is closely linked to the quality and quantity of inputs, the nutritional value of specific livestock wastes, in fresh or processed form, is also an important descriptor.

Most fish production data for culture systems fertilized with livestock manure are based on feedlot systems but wastes from animals raised in scavenging systems can also be used. Clearly the latter waste is less easy to collect than waste from animals confined continuously. Some livestock wastes are more acceptable than others; whereas poultry manure from broiler houses is easy to handle and is used widely in agriculture, pig manure is often less acceptable for logistic, religious or aesthetic reasons.

Whilst the concept of carrying capacity in terms of number, or biomass, of fish or livestock that can grow per unit area is similar, the necessity to maintain adequate water quality, especially dissolved oxygen, is critical in aquatic systems. Both production and processing of livestock generate by-products that can be used for aquaculture. Direct use of livestock production wastes is the most widespread and conventionally recognized type of integrated farming. Production wastes include manure, urine and spilled feed; and they may be used as fresh inputs or be processed in some way before use.
Animal required per ha

- Healthy cow: (400-450Kg): 4,000-5000kg dung and 3,500-4,000 litres urine annually. 5-6 cows adequate for 1 ha pond.
- Waste produced by 30-35 pigs = 1 ton Ammonium sulphate. Floor space: 3-4 sq.mt/pig.
- Adult Pig releases 500-600 kg dung annually. 40-45 pigs adequate for 1 ha. Pond
- Poultry space 0.3-0.4 sq.mt/bird. 1000 nos for 1 ha area. or 300-400 nos/ha
- Duck 450-500 nos.per ha
- Goat .50-60 nos for 1 ha

Fish pond Management:

- Local resource levels are affected by both physical e.g. soils, topography, water availability, and social and economic factors that can foster or constrain the development of integrated practices.
- Stable and high water temperatures and sunlight ensure year-round growth of both fish and their natural feeds.
- The tropics, in which average monthly water temperatures remain above 18°C, are ideal for culturing fish using livestock waste as inputs, although it is also practiced in sub-tropical and temperate climates during warmer periods of the year.
- Manures can be used fresh, or after processing, to enhance natural food production in sun-lit ponds.
- Although some nutrition may be derived directly from the waste, high-protein natural feed produced on the nutrients released from the wastes mainly in the form of plankton is more important.
- Fish feeding low in the food web, e.g. carps and tilapias, benefit most from this type of management since they can utilize plankton, benthic and detrital food organisms effectively.

Pond design, depth, shape and position also contribute to maintaining water quality since these factors affect exposure to wind, sunlight and run-off from adjacent land.

Conclusion:

The advantages of integration are obvious. As far as fish production is concerned, it serves the major purpose of providing cheap feedstuffs and organic manure for the fish ponds, thereby reducing the cost and need for providing compounded fish feeds and chemical fertilizers. By reducing the cost of fertilizers and feedstuffs the overall cost of fish production is reduced and profits increased. The study group was told that the profit from fish culture is often increased 30-40 percent as a result of integration. Secondly, the overall income is increased by adding pig and/or poultry raising, grain and vegetable farming, etc., which supplement the income from fish farming. Thirdly, by producing grain, vegetables, fish and livestock products, the community becomes self-sufficient in regard to food and this contributes to a high degree of self-reliance. Fourthly, the silt from the ponds which is used to fertilize crops, increases the yield of crops at a lower cost and the need to buy chemical fertilizer is greatly reduced. It is estimated that about
one third of all the fertilizer required for farming in the country comes from fish ponds. Integrated farming calls for skill in different types of activity such as raising pigs and poultry, crop and vegetable farming, growing grass and aquatic plants and farming of fish. One person can take care of 6-8 ponds or 30-50 pigs or 500-1 000 chickens, but many of the activities, including harvesting, will need a large number of people. Obviously, if integrated farming has to be done on a large scale, a sufficient number of people with the required skills have to work together.

[Source: Little and Edwards, 1999; Chen et al. (1994); Cremer et al. (1999); Edwards (1993); Diana et al. (1996)]
Strategies for enhancing fish production under various climate resilient IFS models

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"A systems approach is essential to understanding sustainability. The system is envisioned in its broadest sense, from the individual farm, to the local ecosystem, and to communities affected by this farming system both locally and globally. A systems approach gives us the tools to explore the interconnections between farming and other aspects of our environment." In recent years, food security, livelihood security, water and nature conservation and environmental protection have emerged as a major concern in the worldwide. It has been accepted by everyone across the globe that sustainable development is the only way to promote of resources and environmental protection without hampering economic growth. To make the farming economically viable, and environmentally sound and sustainable a holistic all-around approach is required to be stimulated. To meet the multiple objectives of poverty reduction, food and nutrition security, competitiveness and sustainability, the integrated farming systems approach is considered to be the paramount activity. A farming system is the result of complex interactions among a number of inter-dependent enterprises, where an individual farmer allocates certain quantities and qualities of four factors of production, such as land, labour, capital and management. Integrated Farming System (IFS) is an approach that can lead to a quantum jump in the productivity on a sustainable basis and ensure better livelihood securities to the people in fragile ecosystems. It is a powerful tool for natural and human resource management in developing countries like India. It is a multidisciplinary whole-farm approach and can be effectively employed in solving the problems of small and marginal farmers.

Food fish production, as is the case in all other primary production sectors, is expected to be influenced and or impacted to varying degrees by climate change and the manifestations thereof are expected to occur in varying forms and to varying degrees in different parts of the world. However, unlike other animal food production sectors, food fish production is divisible into two subsectors: capture fisheries which overly depend on naturally recruited and occurring wild populations, the great bulk (approximately 85 to 90 percent) of which are in the oceans; and the cultured or farmed food fish subsector, that is growing in relative importance and is popularly referred to as “aquaculture”

Asia has been the cradle of integrated crop-livestock-fish farming systems, which have evolved since the inception of human civilization particularly when human settlements started moving inland leaving the river banks. Though there are several successful practices of integrated fish farming in Asian countries including India, the system of farming using synergizing scientific integration of agriculture, aquaculture and livestock farming are not yet widespread in the region.
Fish production under Various Climate Resilient IFS Models can be discussed two distinct geographical locations. The upland Integrated farming system which is usually found in mountainous regions. In this system fish pond can be constructed suitable locations either close to the house so that the domestic and kitchen wastes are drained into the fishpond or the livestock pens and garden are also situated near the pond and garden includes a variety of vegetables and fruits (i.e. banana, orange, peach, apricot, etc.) and other crops, including sugarcane, tea and cassava. This provides a mix of perennial and annual crops. In this system, a portion of the livestock manure is used for manuring the trees and vegetables. Trees are manured once or twice a year; vegetables are manured according to their needs. Pond silt is removed every 3-4 years and used as fertilizer. The fish ponds act as a water reservoir for irrigation. Most families keep various animals on the farm, including one or more water buffaloes and cattle, one or more pigs, and several ducks and chickens. The large ruminant animals are allowed to graze or are fed farm by-products. The swine and poultry are usually fed with kitchen wastes, as well as other farm by-products, such as cassava, rice bran, sweet potato, banana trunks etc. The fishpond is usually allocated a more central part of the farm for better management. Pond area ranges from 0.02 ha to 0.5 ha, with a pond depth of about 1 m. Ponds are often drained after the final harvest, usually in December to February. The pond bottom is kept dry for 1-3 weeks; after which it is cleaned, limed, manured and then filled up with water for restocking. Domestic washings and kitchen wastes are channelled into the pond daily. Integrated farming systems in which nutrients and water inputs are recycled locally. The efficiency of use is improved and has been widely promoted. Although, it can be effective on a small semi-subsistence and larger commercial scales farming system. It also offers a broad range of social and ecological benefits. It has therefore been necessary to adopt a new adaptive and holistic strategy which recognises that integration can take many forms and generate a variety of benefits to multiple users.

The principle of integrated fish farming involves farming of fish along with livestock or/and agricultural crops. This type of farming offers great efficiency in resource utilization, as waste or by-product from one system is effectively recycled. It also enables effective utilization of available farming space for maximizing production. The rising cost of protein-rich fish food and chemical fertilizers, as well as the general concern for energy conservation, has created awareness in the utilization of rice and other crop fields and livestock wastes for fish culture. Integration of crops, livestock with fish farming is a unique and lucrative venture and provides a higher farm income, makes available a cheap source of protein for the rural population, increases productivity on small land-holdings and increases the supply of feeds for the farm livestock. The scope of integrated farming is considerably wide. Ducks and geese are raised in the pond, and pond-dykes are used for horticultural and agricultural crop products and animal rearing. The system provides meat, milk, eggs, fruits, vegetables, mushroom, fodder and grains, in addition to fish. Hence this system
provides better production, provides more employment, and improves the socio-economic status of farmers and betterment of the rural economy.

Integrated fish farming can be broadly classified into two:
1. Agriculture-fish and
2. Livestock-fish systems.

Agri-based systems include rice-fish integration, horticulture-fish system, mushroom-fish system, seri-fish system. Livestock-fish system includes cattle-fish system, pig-fish system, poultry-fish system, duck-fish system, goat-fish system, rabbit-fish system. In the present effort, enhancing Fish Production under Various climate resilient IFS Models some of the components integrate with fish are being discussed.

**Paddy cum fish Culture:**

Rice and fish culture have been a tradition in Southeast Asia including Manipur for over 2000 years. Rice is presently grown in 113 countries. Rice farming also offers a suitable environment for the culture of fish and other aquatic organisms. This rice-based farming system contributes towards food security and poverty alleviation of the country. The history behind integrating aquaculture with different rice ecosystems, the various production systems in operation such as concurrent, rotational and alternate, the modifications needed to the fields in order to integrate fish with rice farming, and the agronomic and aquaculture management that is necessary. Notable changes have taken place in pest management in rice farming, and in fish seed production and availability making this a particularly relevant moment for emphasizing the importance of rice-fish farming.

In India, though six million hectares are under rice cultivation, only 0.03 per cent of this is now used for rice-fish culture. This type of fish culture has several advantages such as (a) economical utilisation of land, (b) little extra labour, (c) savings on labour cost towards weeding and supplemental feeding, (d) enhanced rice yield, and (e) additional income and diversified harvest such as fish and rice from water, and onion, bean, and sweet potato through cultivation on bunds. Considering these, it is imperative to expand fish culture in the rice fields of our country.

The paddy fields retain water for 3-8 months in a year. The culture of fish in paddy fields, which remain flooded even after paddy harvest, serves an off-season occupation and additional income to the farmer. This system needs modification of rice fields, digging peripheral trenches, construction of dykes, pond refuge, sowing improved varieties of rice, manuring, stocking of fish at 10,000/ha and finally feeding of stocked fish with rice-bran and oil-cakes at 2-3% of body weight.

**Soil quality:** Medium textured soils like silty clay or silty clay loam are most suitable for paddy cum fish/ shrimp culture.
Field preparation: The paddy plots should be renovated suitably for the purpose of paddy cum fish farming. Paddy plots in tidal areas where the 1m tidal amplitude is considered suitable for paddy cum fish/shrimp farming. Construction of an earthen dyke surrounding the paddy plot is essential for retaining water and also for holding the fish and shrimp during the culture period. The height of the dyke is required to be maintained between 50 and 100 cm depending upon the topography of the plot. A perimeter canal is necessary on the inner periphery of the plot. For a one ha paddy plot, the width and depth of the canal may be about 2 m and 1 m respectively. The earth removed from excavating the canal may be utilized for constructing or strengthening the dyke. In addition to the perimeter canal, two cross trenches of about 1 m width should also be constructed at both the directions. The area covered by the perimeter canal and the trenches can be about 12-20% of the total land area.

Fertilization of paddy fields: The plots utilized for rice-cum-fish culture is mainly based on organic fertilization with a verities of animal excreta such as poultry dropping, pig excreta, cow dung and waste of plants such as rice husks, waste product of local beer and ashes from household brunt and remains of burnt straws after the harvest is over and compost fertilizer like decomposed straws, weeds and rice stalks etc.

Stocking of fish seeds: Before releasing of fish seed to paddy field the paddy transplantation from rice seed beds to main paddy fields is done in the month of April, and thereafter paddy is left for two weeks for strengthening of paddy roots, the fish seed @ 2500 nos./ha area is released. The fish rearing period varied from 3-6 months and the paddy rearing period is 5-7 months.

Harvesting: Gears use for harvesting fishes is simple bamboo made basket called cane/bamboo. The fish culture for the period of 3-4 months in rice field, a production of 200-300 Kgs/ha achieved and while fish are grown for the period of 5-6 months; 400-500 Kgs/ha yield has been reported in the same season. The methodology used for harvesting used for harvesting, first the water is drained through outlet pipe, and thus allowing fishes and water accumulated in mid-channel of paddy field, thereby the fishes are caught with the help of tasing puda, hand picking etc. and then stocking in large plastic bucket in live condition. After completion of fish harvesting, the paddy harvesting followed. Normally paddy harvesting is made last part of Sept. & Oct. The paddy production range from 3500-4500 Kgs/ha from the same plot of land.

Marketing: fish harvested from the paddy field is marketed at the local market alive or fresh condition because of high market demand, live fish sold @ Rs. 120/- per Kg and fresh fish @ 100/- per Kg. during the lean season, the market price fluctuates. The marginal fish farmer sells their produce in fish market or in the paddy field itself. During the peak season, the fish production from these paddy fields also reaches in the capital markets. During the due rearing period, paddy and fish no chemical insecticide/pesticide/fertilizer application in the entire paddy field.
Horticulture Fish System:
Integration of horticulture and fish is an eco-friendly & very income-generating practice, not only applicable but also a profitable practice for a small & marginal farmer. This is an example of the best-integrated system because it does not require any additional infrastructure in terms of input cost it can use the available space of embankment for grazing horticulture crop. Essential inputs of horticulture crops like seed & seedling of fruits & vegetable are less costly & are available everywhere. This horticulture practice is not so technical. A small farmer is very familiar with this practice. The marketing of horticulture produce is very approachable & easy. In this system, the pond bunds are used for production of horticulture produce. The integration of fish with horticulture has emerged as an effective alternative, highly sustainable farming system with maximum reduction of production cost. The pond was an essential and viable component of the trial with vegetable production system.

Compared to many Farming technologies, horticulture cum fish culture is low-cost technology. It saves farmers time, allowing them to undertake double benefit from the same field or area. Data from the horticulture pond shows the increment in yield of fish as well as vegetable production. It is expected that the higher productivity from the horticulture pond is due to the enrichment of water due to presence of nutrient in the form of organic manure. This is a viable option for augmenting overall farm productivity and better economic return of rural pond based farming community.

Mushroom cum fish: Mushroom shed can be constructed on the dyke of fish ponds. Cultivation of edible mushroom in India is quite recent. Three types of mushrooms being commercially cultivated in India are *Agaricus bisporus*, *Voloriella* spp. and *Pleurotus* spp., commonly known as European button, paddy straw and oyster mushroom. Mushroom cultivation requires high degree of humidity and therefore its cultivation along with aquaculture tremendous scope. Method of cultivation involves use of dried paddy-straw chopped into 1.2 cm bits, soaked in water overnight. Excess water is drained off. Spawn (30 g/kg straw) is added and mixed with wet straw in alternating layers. Perforated polythene bags are filled with substrate and kept in room at 21-30°C with required light and ventilation. The mycelial growth occurs within 11-14 days. Polythene bags are cut open at this stage, water is sprayed twice a day and in a few days mushroom crop becomes ready for harvest. The paddy-straw after mushroom cultivation is utilized for making compost. The compost can be used as manure in various plants growing on the farm as well as in fish nurseries.

Fish-cum-Terrestrial Crop Integration
All or most parts of the crops planted in the fodder crop field and corner plot on the pond dykes and slopes are used as green fodder for the fish and as fertilizers for the ponds. This is the most popular pattern in fish-cum-crop integration.
Crop variety

Crops that are palatable to the fish, rich in nutrition, resistant to disease, easy to manage and have well-developed roots to protect the slope should be used. If the crop serves as a manure, it should decompose easily. High-value crops like chillies, carrot, broccoli, onion, garlic brinjal, beans etc., can be grown in the pond dykes. In upland area in colder area fruit like kiwi, passion fruits etc. can be grown.

Aquaculture can provide large amounts of silt and fertile water for agriculture and land on fish farms has much agricultural potential. The average pond dyke is 3 m wide with a slope gradient of 1:1.5 to 1:3. The mean area of a fish pond is 0.25-0.5 ha. The average ratio of arable land area (pond dyke and slope) to water surface area is 1:5. There is more arable land before May when the water level in the pond is low. With an extra forage field attached to fish pond, in addition, all the areas already available the ratio of arable land area to water surface area could reach 1:2 or even higher. Aquatic plants can also be planted on scattered, unused surface.

It is necessary and feasible to integrate fish farming with crop production to fully utilize pond silt, arable land, and water surface. As a result, the demand for fish feeds can be wholly or partially satisfied.

Fish-Cum-Pig Integration

Fish culture combined with pig raising is a traditional integrated fish farming model in Asia. Now, a few of other countries are also engaged in fish-cum-pig integration. The pig food is often leftover and residues from the kitchen, aquatic plants and agricultural products and their wastes. The pig excreta is in turn used as organic manure in fish ponds. It might keep the environment clean. Pork is the indispensable subsidiary food. Pig manure is of high quality by virtue of nutritional completeness. That's why farmers usually combine fish farming with pig raising and it becomes a common pattern of integration in China’s rural area.

Methods of pig manure application

There are two types of pigsty. One is the simple pig shed constructed on the pond dyke or over the water surface; the other is centralized hog house. Both types have their own merits and demerits. The cost of the simple one is lower and moreover, it’s easy to apply the manure to fish ponds. Therefore, this type is more suitable to household or small-scale farms of fish-cum-pig integration. The excreta of pig can automatically flow or be flushed into the pond. It can save much labour. If the area of a fish pond is less than 0.5 ha a pigsty can be set up on the pond dyke and then, pig wastes after flowing into the pond, can diffuse to the whole pond by virtue of winds and waves. If more than 30 pigs are raised in the same spot, the method of flowing by gravity is not suitable because the more the pigs, the more the pig manure. More often than not the place near the pigsty will be heaped up with manure and the water quality will be partially deteriorated.
In order to fully utilize the effectiveness of manure, it's necessary to pay attention to the method of applying. The manure from the centralized hog house is easy to be concentrated to a storage pond or a sedimentation basin. The amount of application can be controlled by various means. Centralized hog house is fit to be built in large-scaled integrated fish farms.

The manure after dilution can be spread along the pond dyke by manual labour or by small boat in small fish ponds. If the fish pond is large, it's better to use boat and mechanic apparatus so as to spread the manure evenly.

In fish-cum-pig integration, two points must be specially noticed: one is lack of oxygen in the pond; the other is oligotrophic pond water. Therefore, water quality should be monitored regularly. Besides, the production period of pig should match the demand of pig manure in fish farming.

**Fish cum duck farming**

Raising ducks over fishponds fits very well with the fish polyculture system, as the ducks are highly compatible with cultivated fishes. The system is advantageous to farmers in many ways

**Benefits of fish cum duck farming**

Water surface of ponds can be put into full utilization by duck rising. Fish ponds provide an excellent environment to ducks which prevent them from infection of parasites. Ducks feed on predators and help the fingerlings to grow. Duck raising in fish ponds reduces the demand for protein to 2 – 3 % in duck feeds. Duck droppings go directly into water providing essential nutrients to increase the biomass of natural food organisms. The daily waste of duck feed (about 20 - 30 gm/duck) serves as fish feed in ponds or as manure, resulting in higher fish yield. Manuring is conducted by ducks and homogeneously distributed without any heaping of duck droppings. By virtue of the digging action of ducks in search of benthos, the nutritional elements of soil get diffused in water and promote plankton production. Ducks serve as bio aerators as they swim, play and chase in the pond. This disturbance to the surface of the pond facilitates aeration. The feed efficiency and body weight of ducks increase and the spill feeds could be utilised by fish.

Duck droppings and the leftover feed of each duck can increase the output of fish to 37.5 Kg/ha. Ducks keep aquatic plants in check. No additional land is required for duckery activities. It results in high production of fish, duck eggs and duck meat in unit time and water area. It ensures high profit through less investment.

The kind of duck to be raised must be chosen with care since all the domesticated races are not productive. Duck species like Sylhet Mete and Nageswari, Indian runner, exotic species like Khaki Campbell etc., can be used for duck cum fish farming. 200 – 300 ducks are sufficient to produce manure adequate enough to fertilize a hectare of water area under fish culture.2 - 4 months old ducklings are kept on the pond after providing them necessary prophylactic medicines as a safeguard against epidemics. The ducks start laying
the eggs after attaining the age of 24 weeks and continue to lay eggs for two years. The ducks lay eggs only at night. It is always better to keep some straw or hay in the corners of the duck house for egg laying. The eggs are collected every morning after the ducks are let out of the duck house.

Large quantities of feed and manure are added to the fish ponds every year. This results in a considerable amount of residue settling on the bottom of the pond. Moreover, fish and aquatic animal excreted and alluvial soil also settle on the bottom of the pond. The organic material decomposed by bacteria forms a great deal of humus, which combines with the sludge on the bottom of the pond to form silt. The silt is beneficial to the pond as a fertilizer; however, an excessive amount of silt is detrimental to water quality. It accumulates rapidly when large quantities of feeds and manures are applied. The pH of the water will decline, the biological oxygen demand (BOD) will increase, and nitrites and gases such as NH$_3$, H$_2$S, CH$_4$ and PH$_3$ will accumulate and harm the fish.

**Conclusion**

Since animal waste makes good fertilizer for fish ponds, and since 60 percent of the cost of fish farming goes for feed, integrating livestock and fish farming makes sense. Try a combination of different animals and crops that best suit your area. Grow vegetables and other crops on the pond dykes. Use animal waste to run a biogas plant and then feed the biogas slurry to fish—it is better than raw waste as fish-pond fertilizer. The goal is efficiency and higher profits. An integrated fish farm is a multi-trade integrated production complex. There are close binds among all the components, all the management section and between the fish farm and the outside of the farm. These ties exhibit a series of proportional relationships. The main mission of planning and management on an integrated fish farm is to adjust these proportions according to certain conditions and to get a comprehensive balance by quantitative analysis so as to obtain maximum economic returns.
Poultry based business management in NEH region: prospects and strategies

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Introduction

The North-Eastern Region (NER) with a landmass of 2.6 million sq. km located strategically in the eastern part of the country, comprises of seven States (popularly known as seven sisters) namely, in alphabetical order, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura including Sikkim. The region having more than 98 per cent international border (sharing international borders with Bhutan and China in the North, Myanmar in the East and Bangladesh in the South West) has several unique and unparalleled features; fertile land, abundant water resources, evergreen dense forests, high and dependable rainfall, mega biodiversity, flora and fauna and a mixture of socio-economic, political, ethnic and cultural diversity.

Though Agriculture is the prime source of livelihood for the majority (85%) of the rural population in this region, livestock plays as an important role as a component of the mixed farming systems for sustainable livelihood and source of income. The majority tribal population in NE India keeps livestock as an integral part of life, of which poultry plays a major role. Most of the population keeps the bird as backyard system with traditional management practices. The total poultry population in the country is 729.2 million numbers in 2012, of which 4.35 million number are in the NE region (19th Livestock Census, 2012).

Poultry is the most organised sector in animal agriculture, worth rupees one lakh crores. India is the third-largest egg producer in the world after China and the USA and the fourth-largest chicken producer in the world after China, Brazil and the USA. In India, the per capita consumption of eggs has gone up from 30 eggs per annum to 68 eggs per annum, and that of chicken from 400 gms per annum, to 2.5 kg per annum in the last 5 years. Human nutritionists recommend a minimum of 180 eggs & 10 kg chicken per annum for a healthy adult human, which means that the Indian poultry market is laden with opportunities.

In aggregate level in NE states egg production is only two per cent of the total egg production level in the country during 2005-06. Assam is the highest (55 %) producer of egg in the region, followed by Tripura (11%) and Nagaland (9%). Though the country has witnessed a huge leap in egg production during the 1998-99 and 2005-06 but it has been much slower in NE region. The per capita egg availability in NE region is 34 in comparison to national average of 68.

Meat consumers are becoming aware of the scientific nutritive value of egg and meat. Considering the demand of poultry meat and egg in this region, immense opportunities...
prevail in improvement of productivity through adopting scientific interventions in management and health care services.

**What is poultry?**
Poultry consists of generally three categories namely Fowls, Ducks and Turkey & others. The most common and widely raised poultry birds are chicken (Layers: raised for eggs and Broilers: raised for meat production) followed by duck, quail, guinea fowl and turkey.

**What is poultry farming?**
Poultry farming means “commercial rearing of various types of domestic birds for the purpose of meat, eggs and feather production”. Poultry farming can be adopted as a part time or full time business in town as well as in villages on a small scale or large scale basis and can be promoted under the component of Entrepreneurship development and employment/ income generation. The most important need of this business is a great deal of knowledge and experience in the line. In the North eastern region, poultry rearing was once restricted to certain sections of people, but now it has been widely accepted as a popular and profitable business by almost all sections of the society.

Indian poultry industry alone shares approximately 0.6% of total GDP which is around 10% of the total contribution of livestock to total GDP of country (FAO, 2009). Overall growth of poultry industry is 7-8% while for broiler and layer; it is 12% and 8%, respectively (BAHS, 2014). Presently, the poultry industry has worth of approximately Rs. 7500 crores and contributes nearly 1% to the GDP.

Poultry farming is a profitable unique enterprise which comprises both backyard and commercial farming. Commercial poultry farming is necessary to meet up the demand of general population and backyard poultry farming is necessary for rural employment and nutritional security being cheapest animal protein source.

**Table 1: Poultry populations in the North East states of India**

<table>
<thead>
<tr>
<th>States</th>
<th>Poultry</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Hen</th>
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</thead>
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<tr>
<td></td>
<td>Rural</td>
<td>Urban</td>
<td>Total</td>
<td>Cock</td>
<td>Improved</td>
<td>Desi</td>
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<td>55482</td>
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<td>181586</td>
<td>25837</td>
<td>285199</td>
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<tr>
<td>PRADESH</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASSAM</td>
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<td>3309144</td>
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<tr>
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<td>728168</td>
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<td>980878</td>
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<td>109194</td>
<td>669956</td>
</tr>
</tbody>
</table>

**Advantage of poultry farming**

1. Requires minimum investment to start with in comparison to other livestock. Poultry farm structures do not require high maintenance.
2. Rapid return or profit: Chicken start laying eggs when they are about 6 to 8 months of age and broilers chickens take shorter duration to mature and generate profit at the age between 6 to 10 weeks.

3. Poultry can provide fresh and nutritious food and has a huge global demand. Poultry products are not much expensive and hence are affordable. No religious taboo on poultry products.

4. Feed conversion efficiency: Broilers have a very good feed conversion ratio (2.1 -2.3 kg of feed is required by a broiler to produce 1 kg of broiler meat).

5. Poultry provides a continuous source of income: Poultry is not a seasonal industry but gives a good income throughout the year with minimum labour and expenditure (income from eggs, meat, feathers and manure).

6. Farming requires small space: Poultry requires minimum space with modem confinement rearing and may be profitably reared in the backyard of homes.

7. Poultry feeds do not compete with human food: Poultry is capable of utilizing large quantities of by-products like bran, substandard grains and vegetables profitably.

8. Marketing of poultry and its products is easy.

9. Poultry farming creates income and employment opportunities for the people. Unemployed educated youth can easily generate great income and employment opportunity for others through poultry farming. Women and students can also do this business along with their daily activities.

10. Diseases and illness can be minimised by following proper hygiene and care. Diseases are less in some poultry birds like quails, turkeys etc.

11. Poultry gives rich fertilizer: Poultry manure is an extremely rich source of nitrogen and organic material. Hence they are highly regarded as fertilizer. A laying hen produces about 220 g of fresh droppings (75% moisture) every day.

Methods of poultry farming

A. Free-range farming/Extensive system

Free range poultry farming method requires large space for raising the birds. One can rear 200 adult birds/acre of land or 400-500 young birds/acre (Rajini, 2011).

Advantages

- Less capital investment, Less feed cost
- Easy control of diseases by maintenance of clean ground
- Suitable for poultry welfare

Disadvantages

- Not a balanced diet
- More chances of contact with wild and diseased birds
- Difficult to monitor, High risk of predation of birds
- Increased chances for loss of eggs
B. Semi-intensive system

In this system, there will be a pen and run situated or located in a smaller area of land where the pen is surrounded by wire mesh. This system can be used where free land availability is limited.

Advantages
- Makes more economical use of land as compared to free range system
- Provides protection of birds from inclement weather
- Allows exhibition of natural behaviour
- Suitable for duck and geese rearing.

Disadvantages
- Needs regular cleaning of the run
- Chances of contact with wild birds
- Not suitable for broilers

C. Intensive farming

Intensive poultry farming method is a highly efficient system which saves land, feed, labour and other resources and increases production. It ensures continuous production throughout the year in any environment and seasons. The birds can be kept under continuous supervision. World watch institute described that “about 74% of total poultry meat and 68% of total poultry eggs production is from intensive poultry farming method”.

Disadvantages
- Cost of construction is high
- Animal welfare is compromised
- Rapid spread of diseases

Scopes of poultry farming

1. Broiler Farming
Modern broiler farming methods produce birds suitable for consumption within 5 to 6 weeks of age with body weight of 1.5 to 2 kg.

2. Layer Poultry Farming
Commercial hen generally starts laying eggs at the age of 17-20 weeks, attains peak at 25 weeks of age and laying continues upto 70-72 weeks with the production of more than 300 eggs/ year.

3. Organic Farming Methods
Organic farming method is almost the same as free-range farming systems which promotes animal health and environment sustainability. But the main difference is that, in organic farming methods the birds are not allowed for randomly using of in-feed or in-water medications, other food additives and synthetic amino acids. This system is very suitable for the poultry breeds which reach slaughter weight slowly (around 12 weeks).
Global organic production has increased 20% annually over the past 10 years due to increasing consumer’s acceptance. So the premium market for organic farming can be a boost for improving poultry production.

4. **Contract farming/Integrated farming:**
Association between integrator and the producer, lesser production cost, higher productivity were the fruits of dual efforts of the Integrating Company and the farmers. Integrator provides all inputs i.e. chick, feed, vaccine, medicine and veterinary services and also provides the income to the farmer by way of Growing charges. The farmer from his part manages the farm and tries to perform well and get higher income. The farmer also gets an additional income by way of selling the manure at the end of every batch. The end result is that the consumer gets the poultry meat at affordable prices, the farmer gets his regular income and the company expands the volume of business and productivity. It provides good number of employments for rural and urban youth and nutritional security.

5. **Rural poultry / Backyard farming**
Rural Poultry is a good occupation for the rural masses for economic sustainability and nutritional security. Many countries have adopted Poultry as a micro enterprise with women empowerment as a model for rural economic sustainability. Rural Poultry involves Chicken Farming, Duck Rearing, Turkey, Quail and Guinea Fowl Farming with minimum available infrastructure and open range farming. The Government of India has formulated policies to support and augment rural poultry which contributes nearly 30% of revenues in the poultry sector. It is suggested that these formats are made better sustainable with usage of locally available materials such as food grain waste, floor mill waste, vegetable waste etc., to keep the cost of production at a minimum. There are two benefits one can derive by way of rural backyard Poultry Farming namely Income generation by selling eggs or Poultry for meat and the major benefit would be supplementing the household nutritional requirement by way of self-consumption to the needy. Basic concept of rural poultry revolves around production of coloured variety of chicken similar to Desi or Local variety with a higher performance outputs namely more body weight gain and more egg production under low input technology conditions (Rural poultry management guide, CPDO)

6. **Designer egg production**
Eggs are considered as complete food with most of the nutrients required for well beings. But the worries are related to the cholesterol content found in the egg. In addition to the nutrients already available in the egg if we can alter or incorporate certain health beneficiary nutrients then these eggs will be the choice of food for health conscious peoples and it can also reduces the chances of occurrence of certain diseases. The level of cholesterol in modified eggs is 190 mg per egg in comparison to 215 mg in generic eggs. However, the organic and free range eggs are marketed as value added eggs (Watkins, 1995). In India, Narahari et al. (2004) have built up an Herbal Enriched Designer
Eggs (HEDE) which is not only rich in n-3 PUFA but also have Vit. E, Se, carotenoids, B-complex vitamins and trace minerals.

7. Value addition of products
With the shifting of lifestyle among the people of the region, introduction of value added chicken products will fetch a high price in the market.

8. Poultry products for medicinal use
Chicken eggs are used to produce source of molecule to treat snake bite. Duck embryos are used to manufacture anti rabies vaccine. Diet eggs and designer eggs will act as vitamin E substitute, omega fatty acids and antioxidant requirements. Poultry eggs and meat have got sensorial, curative, nutritive and therapeutic potential.

Issues of poultry farming in NEH Region

1. Inadequate availability of superior germplasm
The indigenous poultry are still occupying the majority of the tribal population in NE region of India. The problem faced by the poultry farmers in the region is the lack of easy availability of good quality chicks.

2. Inadequate availability of quality feed
In traditional system, birds can usually find enough food to keep them alive, in the open. But when they are kept in confinement, they require more attention in feeding to grow well and produce maximum egg. The main problem faced by the poultry farmers in the region is no availability of quality feed. Except the rice polish and a portion of required maize, all other feed ingredients are to be brought from outside the state. Due to high transportation cost, farmers have to pay more in feed than their counterparts in other states of the country. Again, due to the adverse geo-climatic condition (especially in rainy season), lack of proper storage facilities, feeds cannot be stored for a longer period in summer.

3. Lack of infrastructure and proper storage facility
Eggs and poultry products can be held for a long period under cold storage. However, when the demand goes down or surplus products small farmers of the state face problem due to non-availability of cold storage that results in wastage. Fresh meat slaughtered immediately at roadside is more preferred than package meat.

4. Unorganised marketing and perishability of poultry products
There are no organized markets in all the states of NE India, which involves chains of middlemen who reap the actual benefit depriving the real producers of their rightful share. Wide fluctuation of price for both egg and poultry meat is another constraint. Marketing of the eggs and poultry products in rural areas are through the daily or weekly bazars directly by the farmers. In urban areas, the demand of eggs and poultry is met mainly from Surplus eggs and broilers of the rural areas or supply from the outside state.
5. **Electricity tariff**

In poultry farming electricity is used for various purposes viz. hatching, brooding lighting, processing, storing etc. Therefore higher electricity charge reflected to costlier poultry products.

6. **Inadequate availability of veterinary health service**

Disease control of poultry is one of the sectors, which has not received much attention in the state. Apart from city and towns, practically no disease diagnostic facilities are there in the state. Often poultry farmers do not take the burden of taking few dead chicks in the flock to a distant place for post-mortem examination, as they normally do not realise the importance of diagnosis of poultry disease through post-mortem examination. Farmers suffer severe loss due to diseases mainly Ranikhet and Bird flu. The farmers have to face various problems in treating the disease affected birds because of

i) **Lack of awareness and alertness of the farmers**

This is also responsible for the outbreak of disease. They do not pay proper attention to the scientific advices or unable to understand the impact of the advice perfectly.

ii) **Absence of disease-diagnostic centre**

The farms which are situated far from cities and towns do not have disease diagnostic facilities.

iii) **Financial constraints**

Undoubtedly, finance is another constraint to treat the diseased bird properly, as treatment requires sufficient financial involvement to face such emergencies.

iv) **Scarcity of drugs, medicine etc.**

There is a scarcity of drugs and medicine for the treatment. The required medicine is often found to be insufficient at the market which caused a great inconvenience to the poultry farmers.

v) **Quality of medicines/vaccines**

There are many incidences that the medicines/vaccines used in the farms are ineffective. It is alleged that sometimes the old, expired medicines are being released in the market with new label. On the other hand, medicine depot/pharmaceuticals bother least about the quality maintenance of vaccines. Many a times it has been found that vaccines that need cold storage are kept in room temperature.

1. **Managerial problems**

For a profitable egg and broiler enterprise, a good management is essential. Since most of the poultry production is at village level the concept of good management practices are negligible. There are no quality standards in farm management in India and lack of comprehensive regulating authority to maintain hygiene, and granting of licenses for poultry farms.

2. **Technical constraints**

The farmers mainly in the rural areas still use the traditional method of poultry rearing i.e. no proper housing, use of unhygienic equipment of feeding etc. They have not yet
prepared to adopt uncoloured bird (improved). They still feel that their desi coloured birds are much better in traditional system of rearing. There is Lack of knowledge about scientific rearing system, scientific disease management, importance of quality feed, Lack of awareness about improved breeds

3. Lack of easy credit facility
Finance is also a formidable problem to the prospective poultry farmers of the region. Except very few, they cannot afford to invest in poultry farming.

4. Low productivity
This is because poultry farms use open buildings, no climate control and high risks related to low productivity of Eggs and growth in chicken.

Strategies of poultry production in NEH region:

1. Availability of good quality: There should be availability of good quality breeds suitable for backyard also to the farmers so as to improve the productivity.

2. Transformation of backyard poultry into small scale intensive system: Though backyard helps in rural economy, the farmers should be trained to take up poultry with small scale intensive system for more income generation.

3. Establishing a compound feed manufacturers: The Government should encourage establishment of compound feed manufactures unit for exploiting non-conventional feed resources, to produce economic ration. The cost of concentrate feed is very high in this region as it is imported from other states of India.

4. Extension of health care services: Timely prophylactic measures and emergency of services for treatment of poultry should be made available. Inefficient health care services and lack of availability of medicines and vaccines are the main cause for the failure of poultry production system NE India. There should be proper monitoring and surveillance for emerging and trans-boundary disease which are not endemic to India (Avian Influenza, VVND).

5. Modern disease diagnostic laboratory: There should be modern disease diagnostic laboratory to keep strict vigilance on diseases and their prevention. Unfortunately, most of the farmers neglect diseases and parasite infestation at the early stage which result in serious problems eventually leading to serious losses in the productivity and profitability. It has been proved that adoption of treatment after outbreak of diseases is more expensive.

6. Availability of modern Slaughter House with cold storage facility: Slaughter house or abattoir should be made killing the animals under hygienic condition for human consumption. The slaughter house plays a vital role in supplying quality and wholesome meat to the consumers. So the slaughter house should have adequate facilities for potable water, electricity, drainage and effluent disposal system, cold storage, quality control laboratory, space for ante-mortem and post-mortem inspection, by-product utilization system etc. The local butchers should also be made
to slaughter the animals only in the slaughter houses with the payment of minimum fee to the concerned authority.

7. **Establishment of organized market**: Establishment of organized networks of market so that the livestock farmers get due share for their products. Organized market involves participation of Government institution or Co-operative federation. The basic motive of the organization is to see that the consumer price doesn’t fluctuate violently. This will eliminate the middlemen and the farmers will get the fair price of their products.

8. Development of reliable and stable market chain round the year for marketing of poultry products. Facilities for hygienic slaughter and preservation of eggs should be made available at market places in both urban and rural areas. Formation of producer co-operatives/ associations and rural market yards will help in proper marketing.

9. **Technical Guidance and Training**: In order to solve the issues, specialized poultry networks and training programs should be introduced in order to provide awareness to the farmers about the various diseases, health conditions, strategies and techniques which are necessary to ensure the quality of poultry products and for the better health of the chickens, ducks and other domesticated animals. The veterinary department should also organize publicity programmes through different media such as books and pamphlets, TV and Radio broadcasting, exhibition etc. regarding scientific system of poultry farming.

10. **Organic poultry production**: Consumer’s awareness is growing in terms of organic food products in recent years. So the farmers should be made more aware of organic poultry production.

11. **Value addition in Poultry**: Value addition in poultry plays in important role in increasing the profits. The value addition may be through nutritional manipulations, processing and transgenesis.

**Conclusion**

Poultry farming in India has transformed into a techno-commercial industry from the status of backyard farming since last three decades. With increasing demand for chicken egg and meat, the poultry production foresees further expansion and industrialization. This production is achieved generally by commercial poultry operations; however, a significant contribution comes from rural poultry also. Adoption of small scale poultry farming in backyards of rural households will enhance the nutritional and economic status of the rural people. Increasing consumer awareness for organic and enriched egg and lean meat has also opened a premium market for poultry farmers. The diversified poultry farming i.e. quail, turkey and guinea fowl are also gaining momentum due to their high productivity, gamy flavour of meat and disease resistance. Emu farming is spreading its wings as an emerging enterprise due to medicinal value of its meat, oil and for leather production. Production of biogas from poultry dropping and litter adds extra revenue and reduce environmental pollution. The development of poultry through the application of modern science and technology will greatly contribute to improving the socio-economic
conditions of the poor farmers by making poultry farming more productive and remunerative. The introduction of better stock and efficient husbandry practices with an efficiently organized marketing system would make poultry a successful enterprise for Indian farmers. With the advent of knowledge and new discoveries in different fields of poultry, the future challenges will not be a hindrance and thus sees a bright future for poultry production in this region.

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http://www.fnbnews.com/Poultry/Poultry-farming-in-India-and-its-future-prospects


A to Z of poultry farming and its integration with integrated farming system (IFS)

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Poultry

Poultry is one of the fastest growing industry among livestock sector in the world. Poultry meat accounts for about 27% of the total meat consumed worldwide and its consumption is growing at an average of 5% annually. Poultry industry in India is relatively a new agricultural industry. Till 1950, it was considered a back yard profession in India.

Breeds: Specific poultry stocks for egg and broilers production are available. A majority of the stocks used for egg production are crossed involving the strains or inbred lines of white Leghorn. To a limited extent, other breeds like Rhode Island Red, California Grey and Australorp are used. Heavy breeds such as white Plymouth Rock, White Cornish and New Hampshire are used for cross-bred broiler chickens. Hence, it is essential to consider the strain within the breed at the time of purchase. Several commercial poultry breeders are selling day old chicks in India. It is best to start with the day old chicks.

Housing: Adequate space should be provided for the birds. Floor area of about 2 ft² per adult bird is adequate for light breeds such as white Leghorn. About 3 to 4 ft² per bird is required for heavy breeds as well as for adult ducks and turkey birds. Floor space allowance for broilers is 0.5 sq.ft per bird upto 18 days and 1.1 sq.ft per bird upto market age. The house should have good ventilation and reasonably cool in summer and warm during winter; it should be located on well-drained ground from flood waters.

Feed: The feed conversion efficiency of the bird is far superior to other animals. About 60-70% of the total expenditure on poultry farming is spent on the poultry feed. Hence, use of cheap and efficient ration will give maximum profit. Ration should be balanced containing carbohydrates, fats, minerals and vitamins. Some of the common feed stuff used for making poultry ration in India are:

Cereals: Maize, barley, oats, wheat, pearl millet, sorghum, rice-broken.
Cakes/meal: oil cakes, maize-gluten-meal, fish meal, meat meal, blood meal.
Minerals/salt: Limestone, Oyster shell, salt, manganese.

From the day old to 4 weeks of age, birds are fed on starter ration and thereafter finisher ration, which contains more energy and 18-20% protein. Feed may be given 2-3 times. In addition to the feed stuff, antibiotics and drugs may also be added to the poultry ration. Laying hens are provided with oyster shell or ground limestone. Riboflavin is particularly needed.
Health care and sanitary measures: The vaccination programme varies from place to place and time to time, depending on the prevalence of diseases in the area. The chicks must be vaccinated against Ranikhet diseases with F1 Strain or lasota vaccine within the first 6-7 days of age. One drop of vaccine may be administered in the eye and nostril. Booster for Ranikhet can be given at age of 28 days to 30 days of age. Deworming should be done every month or once in 6 weeks in deep litter system and once in two months in case of cage system. Killed vaccine for Ranikhet can be given intramuscularly or subcutaneously when birds are 8 weeks old and should be repeated here after every 8 weeks interval. Proper disinfection of farms with suitable disinfectants and strict bio security measures should be adopted in and around farm surroundings.

Maintenance: The thermoregulatory mechanism of a newly hatched chick is not well developed and takes about two weeks for this mechanism to develop fully and maintain homeostasis. Therefore chicks cannot maintain the body temperature properly for the first few weeks of life and may be subjected to chilling if not properly taken care off. Under these circumstances, artificial brooding is mainly aimed at providing extra heat or warmth during the first two to three weeks of life. Brooder mash with 22% crude protein and 2700 Kcal/kg of metabolisable energy has to be prepared and provided. When birds get the optimum body weight of 1.0-1.5kg around six weeks, they can be marketed for broiler. Hens may be retained for one year for production i.e. upto the age of 1½ years. After that, they are disposed off for table purpose. It may not be economical to keep the hens beyond 1½ years since egg production would get reduced. One hen is capable of laying 180-230 eggs in a year starting from the 18 to 20 weeks. In addition, a laying hen produced about 230 g of fresh droppings (75% moisture) daily. Some of the materials which are commonly used as litter are paddy husk, groundnut hulls, saw dust, wood shavings, chopped straw and even sand. The choice of litter material depends mostly on cost and local availability of the material. A total litter height of 5 cm is sufficient and should be maintained practically dry. Moisture level in litter material will go up every day because of water in birds droppings. If it goes beyond 25%, excess ammonia will be produced. If ammonia level in the atmosphere exceeds 25 ppm, the birds will be subjected to various stresses. There will be eye irritation, conjunctivitis, poor feed intake and growth rate. The birds will be predisposed to diseases like coryza, bronchitis and coccidiosis. When litter remains wet even after raking, add some more fresh litter material. Addition of super phosphate at 2 kg/100 sq. ft area will help in reducing ammonia level. Addition of lime powder is not advisable.

Integrated farming system (or integrated agriculture) is a commonly and broadly used word to explain a more integrated approach to farming as compared to monoculture approaches. It refers to agricultural systems that integrate livestock and crop production or integrate fish and livestock and may sometimes be known as Integrated Bio systems. In this system an inter-related set of enterprises used so that the “waste” from one
component becomes an input for another part of the system, which reduces cost and improves production and/or income.

The concepts associated with IFS are practiced by numerous farmers throughout the globe. A common characteristic of these systems is that they have a combination of crop and livestock enterprises and in some cases may include combinations of aquaculture and trees. It is a component of farming systems which takes into account the concepts of minimizing risk, increasing total production and profits by lowering external inputs through recycling and improving the utilization of organic wastes and crop residues. In this respect integration usually, occurs when outputs (usually by-products) of one enterprise are used as inputs by another within the context of the farming systems. The difference between mixed farming and integrated farming is that enterprises in the integrated farming systems interact eco-biologically, in space and time, are mutually supportive and depend on each other.

**The Goals of this Integrated Farming Systems Manual (IFS) are to:**
- provide a steady and stable income rejuvenation/amelioration of the system’s productivity and
- achieve agro-ecological equilibrium through the reduction in the build-up of pests and diseases, through natural cropping system management and the reduction in the use of chemicals (inorganic fertilizers and pesticides).

**Advantages of IFS**
- It improves space utilization and increase productivity per unit area
- It provides diversified products
- Improves soil fertility and soil physical structure from appropriate crop rotation and using cover crop and organic compost
- Reduce weeds, insect pests and diseases from appropriate crop rotation
- Utilization of crop residues and livestock wastes
- Less reliance to outside inputs – fertilizers, agrochemicals, feeds, energy, etc
- Higher net returns to land and labour resources of the farming family

**Fish culture cum duck rearing:**
Fish cum duck integration is very common in countries like China, Hungary, Germany, Poland, Russia and to a very small extent in India (Ayyappan et al., 1998). As small scale farmers comprise the bulk of the population in India, their socioeconomic conditions encourage them for fish cum duck integration to raise farm productivity (Edwards et al., 1988). From the viewpoint of input-output relationship fish-cum-duck integration is the best model of integrated fish, livestock and poultry. In this integrated system ponds provide living and foraging areas for the ducks and fish. Similarly, ducks provide eggs for home consumption and manure for the ponds. This type of integration can increase overall production intensity and economics on land, labour and water requirements for both poultry and fish. For example, one hectare of static water fish ponds can process the
wastes up to 1500 birds, producing fish in quantities of up to 10,000 kg/hectare without other feeds and fertilizers. Also, since effluents are few, environmental impacts are minimal (Little and Satapornvanit, 1996).

Ducks are reared in shelters built on the banks of the ponds or constructed over the ponds on stilts, or sometimes built on floating platforms. The ducks should be kept away from the dykes of the ponds since they search for insects, frogs and snails, damaging the earthen walls with their beaks and provoking erosion and the collapse of the dykes. Fencing inside the pond is therefore recommended. Ducks are known to eliminate almost all the snails in ponds in depths of up to 30–40 cm. Indian runner ducks were reared @ 300 ducks /2.2ha. and advanced fingerlings of Indian major carps (Catla catla, Labeo rohita and Cirrhinus mrigala in a ratio of 3:3:4) were stocked at 6000/ha. Indian major carps in the integrated ponds exhibited better body weight than the control pond. Better growth rate in fishes was contributed to a yield of 2029kg/ha of fish by stocking of ducks in integrated pond than the yield 1286 kg/ha observed in the control pond (Yaswanth Kumar et al.,2012).

**Breeds of duck:** Local ducks have a production potential of about 130-140 eggs/bird/year and are well adapted to local conditions and are quite hardy, more easily brooded and resistant to common avian diseases. Khaki Campbell and Indian Runner are the most popular breeds for egg production. Khaki Campbell Indian Runner has a production potential of 240-260 eggs/bird/year.

**Space requirement for duck:** The ducks do not need elaborate house as most of the time they remain in the pond except during night. A low cost night split bamboo made shelter may be constructed near the pond or at the embankment or on the water surface (floating duck house). Floor space of 3- 4 sq ft is recommended for a bird.

**Feeding of duck:** Ducks generally forage on the pond during day time. Poultry feed and rice or wheat bran at the ratio of 1:2 may be supplemented @100g per day per bird twice a day, once in the morning and another in the evening. The feed should be soaked with water before feeding.

**Duck stocking:** Generally, 200-300 ducks are sufficient to produce manure required to fertilize one hectare of water area. A mating ratio of 1 drake: 6-7 ducks is allowed to attain good fertility and hatchability.

**Fish stocking:** The stocking rates may vary from 8000-8500 fingerlings per hectare and a species ratio of 40% surface feeder (Silver carp and catla), 20% column feeder (rohu), 20-30% bottom feeder (common carp and mrigal) and 10-20% macro vegetation feeder (grass carp) is preferred for high fish yield.

**Time of stocking and harvesting:** It has been suggested to stock the ponds in June-September and to harvest them after about 12 months. The growth of fish is affected, at a water temperature below 18 – 20°C. Hence; it is recommended that the ponds should
be stocked after severe winter. In the Northern and North-western States, they should be stocked in March and harvested in October -November.

**Integrated Duck cum paddy Farming**

Duck farming can be done along with paddy. Ducks consume the weeds and insects in the paddy field and the droplets are useful for increasing the fertility of soil. The local ducks are suitable for duck rearing along with paddy. They do not damage the paddy field. Keep the ducks out of gardens and fields when the plants are young and tender. The ducks after attaining 2 weeks of age should be allowed in the field after implantation till flowering stage. During collection of the feed in the paddy field, they loosen the soil. Through this mixed farming, the expenses on insecticide and fertiliser are reduced. They are again allowed to paddy field to collect their feed after the harvesting of paddy. Ducks also collect the feed from the water. Under integrated duck farming, the ducks perform 4 essential functions such as Inter tillage, Weeding, Insect control and manuring.

**Integrated poultry-cum-fish farming**

In this system birds may be kept at the floor over the pond or like duck cum fish system poultry house may be constructed at the embankment. Both layer and broiler can be reared. However, in this system, skilled management for poultry and fish are required. About 500-600 birds are required for manuring one hectare of water area. With the integrated poultry - fish farming system, the fish crop is integrated using only poultry droppings or dip litter by rearing the poultry either directly over the pond or on the pond embankment. Poultry fish integration is one of the excellent ways of recycling of all the organic waste efficiently in fish pond as a source of nutrients. Nutrients requirement of fish pond which depends mainly on the nutrients status of pond soil and fish density therein can be fulfilled by supplying needed quantity of excreta by regulating the number of chicks stocked with pond. Integrated fish farming by recycling of poultry manure in fish pond have been reported by Sharma et al., 1998; Sharma and Das, 1988 and Gavina, 1994 in India and abroad.

**Breed of broiler poultry:** Vencob, Hubbard, Phoenix, Cobb, Ross etc.

**Stocking density:** 500-600 broiler poultry in one ha of water area.

**Housing of poultry:** One poultry bird needs 2 sq ft area. Accordingly, shelter may be prepared. House should be well ventilated and protected from predators, snakes, rat etc.

**Feed:** Concentrated feed may be procured or prepared in home. From 0 to 3 weeks of age started feed may be offered and 4-6 weeks of age finisher feed may be given.

**Conclusion:**

While the integrated farming system appears to be a very alternative innovation, its innovation is not as easy as it looks like. It is not merely addition of one or more components to the farmer’s existing system, but, an entirely new farming system which
requires a new set of technological management practices. Different enterprises will have to be involved in this system. The need for keeping all the systems in balance as per requirement of the system because over concentration in one will add to the detriment of the other eg: For manuring a fish pond of 1 Ha water area we require: - 300-400 adult chickens 200-300 ducks. Thus, for integration, the following points must be considered:

1. Productivity and profitability.
2. Technical feasibility and economic viability
3. Socio-cultural adaptability.
4. Sustainability with existing resource and infrastructure

References:


Quality and Green Fodder Production and Management in Hydroponics

B.Sailo, Chongtham Sonia, Norjit Singh, B. K. Sharma Kha Lovingson, Dilrash Mayanglambam and Th. Leena Roy

ICAR Research Complex for NEH Region, Manipur Centre, Imphal

Introduction

Fresh Green fodder is an important component in the diet of livestock. Due to droughts, floods and other adverse climatic factors, the production to meet the demand of the fodder has become a challenge among livestock farmers. In recent years, the production of green fodders has decreased affecting livestock production and health. As the demand and supply of the green fodder for livestock is increasing, there is a need for alternative method for fodder production which would ensure fodder production throughout the year for betterment of livestock production.

The word hydroponics has been derived from the Greek word. Hydro means ‘water’ and ponos means ‘working’ and it is growing of fodder without soil but in water for a maximum of 6 days. The water must be safe for human drinking. You can sprout seeds of barley, maize, oats, wheat or sorghum to obtain fodder for cattle, pigs or poultry.

Benefits of Hydroponics grown fodder:
1. Fodder is produced within a short a time and in a small area.
2. Fodder is completely edible to livestock –they eat the entire mat, roots and green growth. There is no wastage of feed.
3. Water requirement is less and can be recycled.
5. Minimal incidences of pests and diseases.

Current status of green fodder production in the country and the state

<table>
<thead>
<tr>
<th>Category</th>
<th>India (Million hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total geographical area</td>
<td>328.7</td>
</tr>
<tr>
<td>Fodder crops</td>
<td>8.3</td>
</tr>
<tr>
<td>Green fodder deficit</td>
<td>60 – 65%</td>
</tr>
</tbody>
</table>

Protocol for producing green fodder in Seven days cycle in Hydroponics unit:
1. Select seeds without overgrowths and free of chemicals.
2. Disinfect seeds by soaking in diluted chlorine solution (similar to what is used to disinfect drinking water) for 2 hours to prevent mould/fungus growth.
3. Drain chlorinated water and rinse grains then soak the grains in water for 24 hours to promote water uptake by the grains.
4. For grain sowing, measure 2kg of grains for each tray that measures 80cm by 40cm.
5. Spread the grains on the trays evenly (not over 3cm deep) to provide enough space for each seed to sprout.
6. Ensure your tray has holes that are evenly spread at the bottom for proper drainage of water.
7. Transfer the trays to the hydroponic unit. Germination of seeds begins at this point and is considered day 1.
8. Irrigate from day 1 to day 6 at intervals of 4 hours in every 24 hours (30 seconds for automated system and 1 minute for manual system).

**Feeding Hydroponics grown fodder to Livestock:**

**Cattle:** Provide 8kg of the hydroponic barley to replace 2.5kg dairy meal in addition to hay and silage.

**Pigs:** At fattening stage provide 3kg of hydroponic fodder and 2kgs of dry feed.

**Poultry:** For 100 layers provide 8kg of hydroponic fodder in addition to 4kg of layers mash per day.

**Nutritional content of Hydroponics grown Maize:**

<table>
<thead>
<tr>
<th>Particulars</th>
<th>(% on as such basis)</th>
<th>(% on dry matter basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>86.75</td>
<td>-</td>
</tr>
<tr>
<td>Crude Protein</td>
<td>1.90</td>
<td>14.35</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>1.79</td>
<td>13.54</td>
</tr>
<tr>
<td>Ether Extract</td>
<td>0.48</td>
<td>3.64</td>
</tr>
<tr>
<td>NFE</td>
<td>8.62</td>
<td>65.08</td>
</tr>
<tr>
<td>Ash</td>
<td>0.45</td>
<td>3.39</td>
</tr>
</tbody>
</table>

**Hydroponics vs Conventional Farming:**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Hydroponics</th>
<th>Conventional farming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control on Environment</td>
<td>Effective control</td>
<td>No Control</td>
</tr>
<tr>
<td>Yield</td>
<td>Predictable</td>
<td>Not Predictable</td>
</tr>
<tr>
<td>Budgeting</td>
<td>Easier</td>
<td>Not Effective</td>
</tr>
<tr>
<td>Aeration of Root</td>
<td>Can ensure adequate aeration of root zone</td>
<td>Cannot ensure</td>
</tr>
<tr>
<td>Pest and Diseases</td>
<td>Controlled</td>
<td>Not controlled</td>
</tr>
<tr>
<td>Temperature &amp; Humidity</td>
<td>Automated</td>
<td>Not automated</td>
</tr>
<tr>
<td>Water Recycling</td>
<td>Can be recycled</td>
<td>Cannot be recycled</td>
</tr>
<tr>
<td>Labour costs</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Soil</td>
<td>Not required</td>
<td>Required</td>
</tr>
<tr>
<td>Water consumption</td>
<td>Low (70 to 80 % lower than conventional farming)</td>
<td>High</td>
</tr>
<tr>
<td>Space requirement</td>
<td>less space</td>
<td>More space</td>
</tr>
</tbody>
</table>
Low cost Hydroponics Green House:
There was a perception that hydroponics fodder can only be grown under Hi-tech nursery and green houses. However, the unit can be made using low cost locally available materials. The low cost unit can be fabricated with Bamboo and wood, MS or GI pipes and plastic pipes. For irrigation: Micro sprinklers (automatic or manually) or a Knapsack sprayer can be used at regular intervals. The cost of Greenhouse unit (30-350 kg fresh fodder capacity daily) made of shade net and wooden material is approximately Rs. 6000-50,000.00. The cost of Greenhouse unit (150-750 kg fresh fodder capacity daily) made of shade net and MS pipe material is approximately Rs. 25,000-1,50,000.00. Home grown or locally available seeds of maize, wheat etc., can be used in this low cost unit (Naik et al., 2013).

Prospects of Hydroponics grown fodder for Manipur:
Hydroponics unit can be incorporated in Livestock based Integrated Farming Systems (IFS) as:

- Dairy cattle Based IFS Model
- Piggery Based IFS Model
- Buffalo Based IFS Model
- Goat Based IFS Model

Manipur is having a total bovine (Cattle, buffalo) population of 3,56,552. There is a huge prospects for low cost hydroponics unit for Dairy cattle farmers as the market cost of concentrated feeds is high. The hydroponics grown fodder can be used as a supplement in the diet of livestock’s and poultry during scarcity season to increase the milk production, to minimize the cost of concentrated feeds and to improve the livelihood of small and marginal farmers.

Reference:
Gender mainstreaming in the context of agriculture and rural development

Kh. Rishikanta Singh and Punitha P

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Agriculture is one of the important sectors of the Indian economy contributing 17.32% share to the total GDP (2016-17). It maintains the economy by providing nutrition, employment and by reducing poverty. The sector provides employment to 58.4% of country’s workforce. For developing agriculture, a number of technological innovations in term of HYV seeds, fertilizers, technical know-how, farm machinery, etc, have been made. But the sector is still underperforming as compared to other developed countries. One of the reasons is poor human resource management which is overlooking the roles and contribution of women. Women make indispensable contributions to the agricultural and rural development. It has been said that rural women are, responsible for 60 to 80% of total food production. Women play a multi-dimensional role by engaging in a number of agricultural activities like sowing, transplanting, weeding, harvesting, intercultural operation, etc. They are also involved in other allied activities like livestock rearing, fodder collection, milking, marketing of farm produce, etc. Along with this rural women are also pursuing the regular household activities like water collection, fuelwood gathering, household maintenance, etc. Many of these activities are not defined as “economically active employment” in national accounts but they are essential to the well-being of rural households. As men participation in agriculture declines, the role of women in agricultural production becomes ever more dominant. In many parts of the world today, there is an increasing trend towards what has been termed as feminization of agriculture. In India, the major cause of this phenomenon is the migration of men from rural areas to towns and cities, in search of better-paid employment. This leads to increase in female responsibility both the field and at home because women have to stay at home in most of the cases. In spite of all the contribution made by women, gender disparity is a persistent feature of rural India. The Gender Inequality Index (GII) which is an indicator derived by taking into consideration the various gender-related aspects shows that our country is far behind i.e. 0.563 compared to China which is only 0.202.

Gender mainstreaming is the process of assessing the implications for women and men of any planned action, including legislation, policies or programmes, in all areas and at all levels. It is a strategy for making women as well as men’s concerns and experiences an integral dimension of the design, implementation, monitoring and evaluation of policies and programmes in all political, economic and societal spheres so that women and men benefit equally and inequality is not perpetuated. The ultimate goal is to achieve gender equality.

As per census 2011, of the 121 million country population women constituted 48.5%. The workforce participation rate which signifies the proportion of workers or employed persons in the total population indicates that females are less i.e. 25.51% against 53.26% for males. Rural sector has a better female workforce participation rate of 30.02% compared to 15.44% for urban sector. Of the total female worker, 41% are agricultural labourers, 24% are cultivators, 6% are household industry workers and the rest 29% are engaged in other works.
Among the various agricultural activities, it has been reported that more than 80 percent of the seed cleaning, sowing, intercultural operations, harvesting, winnowing, drying, cleaning and storage are conducted by female while male is more actively involved in land preparation.

In case of plantation crop, which requires a number of unskilled worker round the year, the participation of women is increasing over the years. According to the report of the Ministry of Labour & Employment (2012-13), the percentage share of women in total employment in plantation crops was around 5 per cent in the year 2000 and has increased to around 56 per cent in 2010. Among the plantation crops, a high percentage growth in women employment has been observed in coffee followed by tea.

Table 1. State-wise women participation in agricultural & non-agricultural activities

<table>
<thead>
<tr>
<th>State</th>
<th>Total Female Workers</th>
<th>% of Female workers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Agricultural Activities</td>
</tr>
<tr>
<td>Assam</td>
<td>1265065</td>
<td>42</td>
</tr>
<tr>
<td>Manipur</td>
<td>229137</td>
<td>56</td>
</tr>
<tr>
<td>Nagaland</td>
<td>279166</td>
<td>83</td>
</tr>
<tr>
<td>Tripura</td>
<td>170238</td>
<td>53</td>
</tr>
<tr>
<td>Bihar</td>
<td>3541857</td>
<td>84</td>
</tr>
<tr>
<td>West Bengal</td>
<td>3528612</td>
<td>33</td>
</tr>
<tr>
<td>Uttar Pradesh</td>
<td>4999389</td>
<td>66</td>
</tr>
<tr>
<td>Orissa</td>
<td>1584529</td>
<td>60</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>5046293</td>
<td>79</td>
</tr>
<tr>
<td>Himachal Pradesh</td>
<td>630521</td>
<td>83</td>
</tr>
<tr>
<td>Rajasthan</td>
<td>4595570</td>
<td>81</td>
</tr>
</tbody>
</table>

Source: Ghosh M.M et al., 2014

The comparison of women participation in agricultural & non-agricultural activities in selected states are given in table 1. It shows that Bihar has the maximum percentage of women involved in agriculture followed by Nagaland, Himachal Pradesh and Rajasthan while West Bengal has the least percentage of women in agriculture. In contrary to this, West Bengal has the largest percentage of women in non-agricultural activities (67 %) followed by Assam, Tripura, Manipur and Orissa. On the other hand, Nagaland and Himachal Pradesh have the least number of female in non-agricultural activities.

In our country, rural women face a number of disparity viz. unequal ownership or access rights to land, lower wages, hard working condition, limited choice of job and alternatives. They are forced to accept labour work in agriculture under very bad working conditions.

In India, average size of land holding (in 2010-11) for male is 1.18 ha while for female it is only 0.93 ha. In the year 2011-12, at all India level on an average, a male agricultural worker get Rs. 138.30 per day while a female gets Rs. 115.30 only. In the year 2014-15, wage rates for male and female field labour were Rs. 268 and Rs. 204 respectively which shows that male workers are getting 31 per cent more than that of female workers. Among the various states, in term of gender wage gap Tamil Nadu top the list with male-
female wage rate of Rs. 303 and Rs. 130 with about 133 per cent difference while the least difference was found in Bihar with the male-female wage rate of Rs. 205 and Rs. 195 with about 5 per cent difference respectively. In case of Assam, the wage gap is about 21% with male-female average wage rate of Rs. 242 and Rs. 190 respectively.

Table 2: Average Daily Wage Rates for Agricultural Occupations in Rural India

<table>
<thead>
<tr>
<th>Occupations</th>
<th>Male (Rs)</th>
<th>Female (Rs)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ploughing</td>
<td>274.15</td>
<td>177.94</td>
<td>35.09</td>
</tr>
<tr>
<td>Sowing</td>
<td>234.34</td>
<td>193.07</td>
<td>17.61</td>
</tr>
<tr>
<td>Harvesting</td>
<td>235.76</td>
<td>196.46</td>
<td>16.67</td>
</tr>
<tr>
<td>Picking tea, cotton</td>
<td>203.45</td>
<td>167.09</td>
<td>17.87</td>
</tr>
<tr>
<td>Horticulture workers</td>
<td>226.24</td>
<td>163.40</td>
<td>27.78</td>
</tr>
<tr>
<td>Inland fisherman</td>
<td>284.20</td>
<td>183.33</td>
<td>35.49</td>
</tr>
<tr>
<td>Animal husbandry (poultry, dairy, herdsman)</td>
<td>185.10</td>
<td>140.69</td>
<td>23.99</td>
</tr>
</tbody>
</table>

Source: GOI, Labour Bureau, 2015

Even within the same agricultural activities also there is a high disparity in wage rate among male and female. The highest disparity was shown in inland fishery where there is wage difference of 35.49 percent followed by ploughing (35 %) and horticultural work (27.78 %). The least differences in wage rate is observed in harvesting, sowing and picking of tea and cotton.

Women suffered from a number of drudgery or dissatisfactory in their work and working environment. Among the various activities, the drudgery reported was highest in case of transplanting and threshing followed by shed cleaning and seed drying activities.

Health Hazards

A number of health hazard are also involved in the in the nature of the work performed by women.


ii) Occupational accident: Over 51% of the total fatal workplace accidents worldwide are comprised of agricultural workers (Forastieri, 2007). Women face higher risks where the use of machinery and exposure to chemicals are greatest.

iii) Ergonomic-related problems: When women use technologies which are intended for male use, it could lead to posture, spine and musculoskeletal problems, or accidents and physical injuries.

Strategies for Gender Mainstreaming

In order to maintain a gender balance approach in the development of agriculture and rural development, the following strategies may be taken up.

i) Development of improved farm tool, equipment and technology which is gender friendly

ii) Organising vocational training and skill development training programs
iii) Special Credit programmes and financial facilities for farm women
iv) Making better use of female extension agents
v) Guidance and support for women co-operatives, SHG, JLGs, etc
vi) Giving women farmers more access to trainings, exposure visits, demonstrations and group discussion.

vii) Innovative credit programmes using collateral free loan for women groups so that farm women are able to obtain access to credit.
viii) Policy interventions for equal access to resources and farm assets.
x) Ensure agricultural policies and programmes are sensitive to gender differences in roles, decision making and activities.

x) Organising Mahila gosthis, farm women days, etc

**Conclusion**

Women’s contribution to agriculture is seldom recognized in spite of their active role in a number of agriculture and related activities. A number of farm activities are predominantly carried out by women as men are not available for search of better job opportunities in urban areas. Women are invariably paid lower wages than men for the same agricultural work. The involvement of women in farm decision making is very less and need to be improved. Drudgery reduction, economic emancipation and better education opportunities are among the key needs of Indian rural women. Women need to be given the right to assess to farm resources as men and financial credit facilities should be provided, after imparting necessary training on skill and entrepreneurship development.

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Role of ICT in integrated farming system

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The information and communication technology (ICT) play an important role in everyday life of an individual. It becomes a vital communication tool cutting across gender, place and also the different classes of society. The agriculture is the mainstay of Indian economy. The people need agricultural information to be passed and received quickly. This paper objective is to highlight the role of ICT in research and extension activities with the special emphasis on Indian experiences.

Information and Communication Technology

The information and communication technology (ICT) play an important role in daily life of an individual. It becomes a vital communication tool cutting across gender, place and also the different classes of society. The agriculture is the mainstay of Indian economy and the major challenge in the present era is improving the production scenario in a situation of waning natural resources required for production. Information unlike other factors of production should be well thought-out as an input factor for sustainable agricultural production. Decade ago there was plenty of literature available on “Digital Divide” that differentiated the countries with IT infrastructure from the countries that were lacking the same. Now that huge investment on IT infrastructure development in rural India by renowned NGOs and funding organizations have neutralized the effect of digital divide and India is in a state to access information virtually. Present hitch is of “Knowledge Divide” or “Information divide” that is getting hold of the pulse. Inadequate and inefficient dissemination of relevant information to the farming sector is the bane to Indian agricultural system and not lack of R&D efforts. The people need agricultural information to be passed and received quickly. This paper objective is to highlight the role of ICT in research and extension activities with the special emphasis on Indian experiences.

Information and Communications Technology (ICT) as defined by Michiels and Van Crowder (2001) ‘is a range of electronic technologies which when converged in new configurations are flexible, adaptable, enabling and capable of transforming organisations and redefining social relations’. They are technologies that can be used to interweave information technology devices such as personal computers with communication technologies such as telephones and their telecommunication networks. ICT is often used as an extended synonym or as an umbrella term for information technology (IT), but is a more specific term (i.e. more broad in scope) that stresses the role of unified communications and the integration of telecommunication networks (telephone lines and wireless signals), computers as well as necessary enterprise
software, middleware, storage, and audio-visual systems, which enable users to access, store, transmit, and manipulate information (Wikipedia, 2015).

**ICT in research:**

This concept has been widely in use and incorporates the theme of participatory methodology. As a case, ICT may be used in farming system research. In this approach, the participation of client i.e., farm men, farm women, youth farmer, other stakeholders and location specific development of technology and dissemination is central to the theme of farming system research and extension. It takes into account the holistic and interdisciplinary nature and targets the multiple goals of the farm family as well as the economic and resource situation in which the farm family operates. The client participatory nature of FSR/E enhances the capability of research and extension organizations to incorporate farmers' goals, resources, concerns with their own future, and their experience into the technology generation and diffusion process and farmers with similar conditions and the specific recommendations are grouped into identifiable recommendation domain (Francis and Hildebrand, 1989). A wide information gap exists between research and realism and the farmers need timely expert advice to become more productive and competitive. The current state of extension agent to farmer ratio as reported by the Working Group Report of the Planning Commission XII five year plan is 1:1500 which makes transfer to technology by traditional approach next to impossible. Though India ranks second highest in number of extension agents (1, 10,000) in the world it is still not enough to meet the needs of efficient and effective ToT (Meera et al., 2010). Traditional Agriculture Extension System is characterised by linearity that includes only the researchers and the farmers excluding all the other stakeholders such as universities, agribusiness traders, non-governmental and civil society organizations that also constitute the networking system of the farming sector through whom the actual agricultural innovations occur. Indian Agriculture extension system is traditionally funded, managed and delivered by the public sector that played a major role in ushering green revolution in Indian agriculture (KM Singh et al., 2013). As today’s farming is becoming highly knowledge intensive, commercialized, competitive and globalised against traditional approach, the call for the precise approach to draw together collaboration between the researchers, farmers, extension workers, agribusiness traders and civil societies will lead to what we aim at “development”.

**Box 1: Need for ICTs**

1. To hasten agricultural growth - need of energetic, vibrant and novel approach to be adopted in order to achieve targeted growth rate and provide the farmers better livelihood by integrating ICT applications in agricultural extension.
2. To increase knowledge reserve - Food security greatly depends on —Knowledge Resource. ICT can complement the traditional extension system for —Knowledge Resource delivery to the millions of the farmers.
3. To aid in better information access - Convergence of ICT with traditional extension system will develop the farmers’ information access.

4. To add-on inadequate technical manpower - Inadequate technical manpower to some extent can be compensated by the extensive use of ICTs.

5. For stronger research-extension client system linkage - Feedback received through ICTs can facilitate stronger linkages with research-extension-client system to be more accurate and quicker.

6. For cost-effective agro-advisory - The ICT tools like Internet and mobile networks provide agro-information services that are relevant, affordable, dynamic, and highly accessible and farmer friendly.

7. To develop knowledge managers - Emergence of knowledge workers result in the realization of bottom-up, demand driven paradigm for technology invention, evaluation, improvement and adoption.

8. To ensure gender equity in technology transfer process - ICT enabled extension system overrides the gender bias and provides equal opportunity to the farm women.

9. To empower small and marginal farmers - Empowering small and marginal farmers with the right information at the right time and at right place is vital for improving effectiveness and liveliness of small and marginal holding.

10. To serve the farm stakeholders beyond technology transfer role – The expanded role of extension systems should be equipped with ICTs should go beyond transforming from new food crop technology to access to export markets.

**ICT engage stakeholders in formulating the ambitious research program:**

ICT plays an important role of enhanced interaction and communication by integrating various stakeholders into research. This results in enhanced communication, wider knowledge and in depth understanding and clarity of the project. The below is the case study which narrates the importance of ICT in research project formulation.

In summer of 2010 four international agricultural research centers of Consultative Group of International Agricultural Research (CGIAR) came together to develop an ambitious research project by consulting various stakeholders on innovative, inclusive research program on livestock and fish. In this program, the various stakeholders were consulted personally as well as online supported by wiki (to enable documents for sharing with all), blog (assumptions and questions were posed and comments were received through this) and survey monkey tools (for several online surveys). For this program the e-consultation began on July 2010 and ended in March 2011. It consists of eight rounds of questions and after five rounds of discussion, initial proposal was formulated. During this period the various e-consultation tools and resources were viewed more than 25000 times and organizers received more than 465 comments and other feedback for the project (Rudgard *et al.*, 2015)
Functional role of ICTs in addressing the information needs of the farmers through the agricultural cycle

The information need of the farmers is a cyclic process and keeps changing along with the cropping period and therefore the information provided should also correspond to the changing information needs accordingly. Of the array of information required, studies has revealed that small farmers rated weather, plant protection (disease/pest control), seed information and market prices as the most important (Mittal et al., 2010.). Almost 46.9% of the farmers said that the biggest constraint they face to improve their productivity is lack of access to any extension service or credible information source (Surabhi Mittal and Mamta Mehar, 2012). At each crop growing stage, the application of ICTs range from that of information providers to diagnostic measures, aid in better decision-making abilities and high price realization of the final produce. When the above cycle is categorized into different sectors of ICT roles we can see that crop plan, seed material procurement, sowing and cultivation come under information providing category, crop protection measures come under diagnostic and advisory category, harvest and post harvest operations and storage and packing can be categorized into decision-making category and marketing of the final produce to the consumers is influenced by the market intelligence. The ICT tools that are used to provide information at the above stages of crop growth are kiosks, CSCs, web portals and mobiles. Using these tools specific need-based information can be provided to the farmers and help them better access to information and enhance their production. Not just advisory information, but a complete resource package across the agricultural value chain needs to be provided (Raj Saravanan et al., 2015).
ICT in Extension: National Experiences

**aAQUA:** almost All Questions Answered. This project was initiated in IIT, Bombay in Pune district, Maharashtra in 2003. This project is sponsored by Media Lab Asia and Development Gateway Foundation. This is a farmer knowledge exchange available at aAQUA.Org answering questions from farmers in four different languages (Hindi, Marathi, English, Hindi). This portal is connected with 72 experts from KVK Baramathi, ICRISAT, UAS Dharwad and its associates, University of Pantnagar and Raichur and its associates. The farmers can register online with a website by having a unique I.D in which all answers are posted under this I.D. The farmers could upload pictures of the infected plants and get diagnosed by the experts with the recommendation. The impact study on the Baramathi region by Agarwal (2005) opine that the information on best practices for cultivating vegetables and onion are valuable in this a-AQUA. Further, the information on sugarcane was very valuable. Before this project, farmers were contacting pesticide shop for plant protection aspects. They also opine that farmers need yellow pages on agro-input shops, information on new methods of cultivation, water release schedule of dams and quick response time from the experts.

**Agriculture Marketing Research and Information Network (AGMARKNET)**

It is a central sector scheme which was launched by the Department of Agriculture and Cooperation and implemented by National Informatics Centre in March 2000. The scheme aims at progressively linking important agricultural produce markets spread all over India and the State Agriculture Marketing Boards/ Directorates and the Directorate of Marketing and Inspection (DMI) for effective exchange of market information. The market information network, AGMARKNET, is being implemented jointly by DMI and National Informatics Centre (NIC), using NICNET facilities available throughout the country. The objective of the scheme is to facilitate collection and dissemination of information for better price realization through Agmarknet Portal (www.agmarknet.nic.in).

**AGRISNET (Agricultural Informatics and Communication Network)**

This was initiated by Department of Agriculture and Cooperation, Ministry of Agriculture, GOI for Rural areas of India in 2002. The Government of India, Department of Agriculture & Co-operation, Ministry of Agriculture launched a Central Sector Scheme titled, “Strengthening / Promoting Agricultural Informatics & Communications” of which one component is AGRISNET. This is implemented by NICNET and Sponsored by Indian Council of Agricultural Research (ICAR) The target group are State/ District Agriculture Department, Allied Department, Agri-Clinic, Agri-Business Centre and the Farming Community.

**Agriwatch portal**

This portal was initiated, implemented and sponsored by Indian Agri-busines Systems Pvt. Ltd. (IASL) in 2001. The objective is to address and overcome the lack of information
available to farming communities and therefore help them plan better and realize higher value. Agriwatch provides subscribers with agricultural market and technical information in the form of newspapers, magazines, SMS, and a website. The target group are Farmers, traders, processors and suppliers etc. The spot market prices of the commodity like grain, pulses, oil seeds, vegetable oil, oil meal, and sugar etc could be known to the nonsubscribers. The price trends of a commodity are known for non subscribers of one week duration and for subscribers it is known up to one year.

Akashganga

This is Implemented and sponsored by Shree Kamdhenu Electronics AKASHGANGA for Western part of India (Mainly Gujarat & Maharashtra) in 1996. The Target groups are Dairy farmers of Anand and other Gujarat & Maharashtra Districts. It conceptualized the need of an Automatic Milk Collection System (AMCS) in early 1990 for ensuring transparency, mutual faith and error-free operations of Milk Collection by integrating Electronics Weigh Scale with Quality testing equipment (EMT or Milk Analyzer) & Data Processor/ Computer.

ASHA

This is Initiated and implemented by National Informatics Centre (Public Sector) for Assam in 2001 and is sponsored by Dept. of IT, Govt. of India. The target groups are farmers, functionaries, scientists, bankers and other stakeholders of the farm sector.

Community Information Centres

This is initiated by Department of Information Technology, Ministry of Communications and Information Technology, Government of India for Arunachal Pradesh, Manipur, Assam, Meghalaya, Mizoram, Sikkim, Tripura, Manipur and Nagaland in 2002. This is Implemented by National Informatics Centre (NIC) and National Informatics Centre Services Incorporation (NICSI) and Sponsored by Ministry of Development of North Eastern Region. The target groups are rural population.

e-Arik

This is implemented by College Of Horticulture and Forestry, central agricultural university (CAU) in 2007. This project was funded by Department of scientific and industrial research (DSIR), Ministry of Science and Technology, Government of India. The target group of this project are tribal faarmers.

Namma Sandesh – Agro Advisory Services through Mobile Telephony

Namma Sandesh is a voice and mobile technology based information dissemination and retrieval service, providing services to more than 10000 plus tobacco farmers in the Mysore district of Karnataka at no cost to the farmers. This service was initiated by ITC LTD The services offered by Namma Sandesh vary from Crop advisory, Market information, Weather forecast information and local news to alerts and reminders. In this
model, the farmers, field staff, content team and the dissemination team are the major parties involved.

**e-Krishi/ Agri-Business centers**

This project is initiated by Akshaya e-Kendra Entrepreneurs for Malappuram District, Kerala in 2005, implemented by Kerala State IT Mission and sponsored by UNDP-ICTD. The target groups are farmers, agricultural input providers, agricultural activists, NGOs and Government organizations.

**Gyandoot**

This is sponsored and initiated by Government of Madhya Pradesh in 2000 and implemented by NIC, M.P. The target groups are tribals and rural population. It covers 311 gram panchayats and over 600 villages which have been covered by 20 Soochanalayas of Dhar District.

**e-Velanmai**

The project was started in July 2007 in Tamil Nadu state with the support of the World Bank and the Tamil Nadu-Irrigated Agricultural Modernization Water and Restoration Management (TN-IAMWARM) project of the Government of Tamil Nadu, India. The overall objective of the action research project, e-agriculture is to provide quality, timely, farm-specific scientific advice with the support of three components namely ICT tools, agricultural scientists and FC to the needed farmers at their farm gate.

**e-Chaupal**

This project is initiated, implemented and sponsored by ITC limited for Madhya Pradesh, Haryana, Uttarakhal, Karnataka, Andhra Pradesh, Uttar Pradesh, Maharashtra, Rajasthan, and Kerala in 2000. The target groups are farmers of these states. There are 6,500 e-Choupals- 40,000 villages in 10 states (Madhya Pradesh, Haryana, Uttarakhand, Karnataka, Andhra Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, Kerala and Tamil Nadu ) affecting around 4 million farmers- soyabean, coffee, wheat, rice, pulses, shrimp . The 'Choupal Pradarshan Khet', brings the benefits of agricultural best practices to small and marginal farmers.

**Jagriti-e-Sewa**

This project was initiated, implemented and sponsored by Jagriti-e-Sewa, Jagriti (NGO) in Punjab in 2003. The target groups are rural population. The focus is on agriculture-Centric Services. The emphasis is on diversification, backward and forward linkages, contract farming and marketing.

**Kisan Call Centres**

This project was Initiated & sponsored by Department of Agriculture & Cooperation (DAC), Ministry of Agriculture, Govt. of India for whole India in 2004. This was initially implemented by Coconut Development Board. The target groups are farmers. The dial
free number is 1800-180-1551. In TNAU Kisan Call Centres, the employee having the qualification of B.sc Agriculture attend the call from farmers and reply their queries from TNAU Agri portal and those queries which is not answered through Agri portal will be contacted the concern experts and answered to the farmers.

**Kisan Soochna Kendra**

This project is initiated by IIT-Roorkee for Uttaranchal in 2005. This was implemented by Jai Kisan. This was sponsored by UNDP, Dept. of IT, Government of Uttaranchal, NIC Uttaranchal. The target groups are Youth

**Community Radio**

Community radio is also known like local radio, farm radio or cooperative radio. Community Radio is owned and managed by the community. Recognizing the importance of communication, the Government of India open access to community radio since 2002. The power of community radio lies in its participatory nature, as it is community oriented where the community members themselves raise issues, voice their concerns and identify their own priorities.

**Online Integrated Computerised systems (OICS) - SUMUL Dairy**

This is initiated, implemented and sponsored by Surat District Co-operative Milk Union Ltd (SUMUL) in 12 district unions, Gujarat since 1999. The target group is the rural population and the farmers.

**Soochna Se Samadhan**

This project has started in 2006 in Himachal Pradesh, Madhya Pradesh and Uttar Pradesh and is implemented by One World South Asia and was supported by UNDP. The target groups are villagers of India.

**KIRAN (Knowledge Innovation Repository of Agriculture in NER)**

KIRAN (Knowledge Innovation Repository of Agriculture in North Eastern Region) is a web platform instrumental in harnessing the scientific knowledge for strengthening the agricultural, production system in NE region. This portal has been launched by ICAR RC NEH, Umiam in collaboration with NIC, Government of India. It targets all the stakeholders of NEH region in the agricultural sectors providing information regarding innovative technologies, agro-advisory services and weather broadcasting services.

**Agropedia**

Agropedia is an online open platform developed by the Indian Institute of Technology Kanpur (IITK), which serves as a one-stop hub for information on the agriculture ecosystem and facilitates exchange and delivery of information between the agricultural community through a web portal and mobile phone networks. The project was launched on 12 January 2009 by Government of India through the NAIP project of ICAR. The aims of agropedia is knowledge management through a repository of knowledge that needs to
be identified, captured, stored and processed via IT tools so that it can be applied further in a new context. The knowledge is disseminated in multiple languages such as English, Hindi and Telugu.

**Expert system**

Expert System is defined as “a computer program designed to model the problem solving ability of a human expert” (Durkin, 1994). It is also defined as “a system that uses human knowledge captured in a computer to solve problems that ordinarily require human expertise”. The expert system of maize is developed by Indian Agricultural Statistical Research Institute (IASRI)

**M4Agrinet**

Media Lab Asia (MLAsia) has taken up a project namely 'Mobile Based Agricultural Extension System in North-East India (m4agriNET) along with CAU, Imphal. The major objective of m4Agri-NEI is to empower the farmers by providing right information on right time by implementing a Mobile Based Agricultural Extension System. The target is around 5000 farmers from 50 villages in 3 districts of Meghalaya over a period of 2 years and provides advisory services to the farmers.

**Rice Knowledge Management Portal (RKMP)**

RKMP is a data-information and knowledge transformation continuum, with about 27000 datasets related to AICRIP multi-location trials conducted over the last 45 years across India. It was started in 2010. RKMP is a initiative under NAIP and developed through collaboration with Directorate of Rice Research, Hyderabad. This portal has various domains serving all sections of the people like research domain, extension domain, farmers domain, service domain, general domain, rice stats, e-learning etc. It has been initiated with an objective to enable rice workers across the country to create, manage, share, scientific, technology related and market related information for the benefit of rice as a sector.

**Decision Support System for Integrated fertilizer recommendation (DSSIFER)**

This software was developed by TamilNadu Agricultural University, Coimbatore. It utilizes location specific fertilizer prescriptions evolved through soil test crop response based Integrated Plant Nutrition System (STCR-IPNS) developed by the ICAR-AICRP-STCR, Department of Soil Science and Agricultural Chemistry, TNAU, Coimbatore and Mitscherlich-Bray percentage sufficiency recommendations developed by the Soil Testing Wing of the State Department of Agriculture, Tamil Nadu to generate crop and location specific balanced fertiliser prescriptions.

**Farmers’ portal**

This portal was developed by Department of Agriculture and Cooperation and Farmers Welfare, Government of India. This portal gives centralized knowledge base or one stop
shop for meeting all informational needs relating to agriculture, animal husbandry, fisheries sectors production and sale/storage of an Indian farmer. In the Farmers’ Portal, a farmer will be able to get all relevant information on specific subjects around his village/block/district or state. This information will be delivered in the form of text, SMS, email and audio/video in the language he or she understands. These levels can be easily reached through the Map of India placed on the Home page. Farmers will also be able to ask specific queries as well as give valuable feedback through the feedback module specially developed for the purpose (Farmers portal). The farmers’ portal has a link to m-kisan portal.

m-Kisan portal

This portal enables all central and state organizations in agriculture and allied activities to give information/service/advisories to farmers by SMS in their language, preference of agricultural practices and location. As per TRAI data of 2014, there are about 38 crore mobile telephone connections and the internet connections is minimal and hence the mobile becomes the suitable ICT tools to expand and spread the communication to 8.93 crore farm families. SMS Portal was inaugurated on July 16, 2013 and since its inception nearly 72 crore messages or more than 210 crore SMSs have been sent to farmers throughout the length and breadth of the country.

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Training Manual on "Integrated Farming System for Sustainable Hill Agriculture: An Option for Climate Smart Agriculture and Natural Resource Management"


Water Management – its significance in sustaining Agriculture in Hill ecosystems – Issues and Strategies

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ICAR Research Complex for NEH Region, Nagaland centre

Water is a vital component of agricultural production and is essential to increase both quantity and quality of produce. Agriculture is the major user of water in most countries and currently this sector faces the enormous challenge of producing almost 50% more food by 2030 and doubling almost 50% more by 2050. This has to be achieved with less water resources, mainly because of increased competition arising out of growing population pressure, urbanization, industrialization and climate change. Over the past few decades, population growth and economic expansion has resulted in increased use and abuse of water leading to greater imbalance between water availability and demand. It is now well accepted that climate change may have large impact on water resources of a region mostly by affecting fundamental drivers of hydrological cycles. Increasing spatial and temporal variability and rainfall patterns (intensity, duration, frequency etc.) under the changing climate are also affecting the availability of utilizable water resources. Other processes like change in population size and location, economic development and land use, infrastructure, ground water development and changing social values etc. also have major influences on water resources and must be considered along with climate change in a holistic approach to water resource management (Brekke, 2009). India accounts for 4.0% of global water resources and 2.45% of land resources. The country also supports 16% of global human and 15% of global livestock resources. India receives about 400 million hectare metres of precipitation annually which is augmented by 20 m ha-m contributed by rivers flowing in from neighbouring countries. Net evapo-transpiration losses are nearly 200 m ha-m. About 135 m ha-m is available on the surface and the remaining recharges groundwater. With growing demand for water from the other sectors, availability of water for agriculture is likely to decline. As such, efficient utilization of water is of utmost importance. India has a highly seasonal pattern of rainfall, with 50 per cent of precipitation falling in just 15 days and over 90 percent of river flows in just 4 months (Sikka and Islam, 2015). India has already facing water stress condition with per capita availability of water declining sharply from 5177 m3 in 1951 to 1544 m3 in 2011 (CWC, 2013). It is projected to reduce further to 1465 m3 and 1235 m3 by the year 2025 and 2050, respectively, under high population growth scenarios (Kumar et al., 2005). The North Eastern Region accounts for 34% (653 BCM) of total water resources and 7.9% of Indian land mass. The per capita availability and per hectare availability of water in this region is the highest in the country. However, less than 5% of the existing potential of the region is so far used for societal use. Against the ultimate irrigation potential of about 4.26 m ha, the area presently under irrigation is only 0.85 m ha. Although the availability of ground water at relatively shallow depth (within 20 m) is
very high in this region, especially in the valley areas, only 4.3 % of the existing ground water potential has been developed so far. The region is endowed with average annual rainfall of 2500 mm with variability ranging from 1200 mm in some parts of Nagaland to 11,000 mm in Cherrapunji (Meghalaya). More than 70 % of the rainfall concentrates in four months (July - September) and unfortunately, the lion’s share of the rainfall particularly in the hilly region is lost as runoff due to peculiar topography and absence of adequate storage device. Among the states, Arunachal Pradesh has the highest average runoff of 350 BCM (53.6 % of NER) followed by Assam 211 BCM (32.3 % of NER) and Mizoram 31 BCM (4.7 % of NER). Total area covered by inland water in this region is 3,320 km². The rivers in the region have a combined stretch of 17,323 km and a total water area of 1817.5 km². Except for Tripura, ground water development is low in other states of North east. Assam has the highest ground water potential among the N.E. states, but presently 12.83 % of ground water is being utilized. The total replenish able ground water resource in Arunachal Pradesh is 1.44, Assam -24.89, Manipur-3.15, Meghalaya 0.54, Nagaland 0.72 and Tripura 0.66 BCM/year. The ground water will continue to play key role in meeting the water needs in spite of abundance rainfall and surface water availability. For augmenting ground water resources, exploration of prospects of development of springs, roof top rain water harvesting, construction of shallow tube wells are some of the welcome strategies. The climate change in north eastern region (NER) is also well perceived in the form of change in temperature, rainfall behavior over times. The annual maximum and minimum temperature from 1901 to 2003 has increased by 1.02°C and 0.60°C respectively. The temperature is projected to rise by another 3-5°C during the latter third of this century (Cline, 2007). The changes in rainfall pattern in NER is well perceived in the form of change in total rainfall, frequent flood, drought etc. The frequent deficits in rainfall and the recurrent droughts in the region further substantiate the climate-induced alteration in the rainfall pattern (Manoj-Kumar, 2011). The change in climate may be due to various causes which may be summarized as due to Natural factors (volcanoes, ocean current, earth’s tilt, variation in solar radiation received by earth, etc.) and anthropogenic factors like – burning of fossil fuel, change in land use pattern, industrialization, urbanization, deforestation, transportation etc. Expected consequences of climate change are warmer conditions, changes in growing period of crops, crop/plant migration, drought, extreme hot weather, storm and heavy rainfall/flood which are likely to bring both threats and opportunities. An average reduction in rainfall by 18 % and rainy days by 9 % in recent times compared to period 1951-1990 in the north eastern region has been reported by Saikia et al. 2012. Agriculture in the N.E.Region is mostly rainfed, subsistence type and suffers from a number of constraints. By and large, the region is characterized by fragility, inaccessibility and marginality. Floods, erosion, landslides etc. are common to the region due to its peculiar topography, geo-physical settings accentuated by faulty land use systems. The farmers of region are mostly small and marginal with small land holdings and low investment capacity. Watershed as a tool for soil and water conservation (SWC)
measures as well as for socio-economic development of community is already a widely accepted fact. The component of the watershed includes socio-economic survey for analysis of resource status, water harvesting structures, construction of bench and half moon terraces along with other agronomic measures for SWC, introduction of HYV crops, fruits and vegetables etc.

An integrated and efficient management of water resources through proper planning is the need of the hour to enhance food, environmental and livelihood security of the fast growing population of the region. This implies management of water along with co-dependent natural resources viz., soil, vegetation, forest, air and other soil biota.

A key challenge for decision makers, policy makers and departments is to understand the strategies adopted by the farmers and other stakeholders in their efforts to address climate change induced water stress. Small holder farmers are most vulnerable to climate change and then have no alternative but to adopt their livelihood system to changing climatic conditions. Water resource management strategy is thus key to ensuring that agricultural production withstand the stresses caused by climate change. The present poor performances in terms of water use efficiency plus competition over diminishing water resources warrant the need for investment in better water management systems. In view of limited access to irrigation, small farmers need to develop water conservation in-situ or ex-situ, rain water harvesting systems to maximize on-farm water management. Water management is also improved by having a greater diversification options for water sources, such as small streams, shallow well, bore well and rain water storage. Other options such as micro-irrigation (drip, sprinkler), water lifting devices (gravity, manual and pumps – motorized, solar etc). Crop diversification and insurance, information management and capacity building among farmers and other stakeholders is also important in the overall strategies of water resource management. Rain water harvesting, proper management of existing water resources, watershed development and community participation will help to attain sustainable utilization of water for agriculture and uplift socio-economic conditions of the people. The stored water in “Jalkund could partly be used for crop production and partly for livestock/fish production. Creating awareness among the people about environmental and anthropogenic facts behind floods, droughts, scarcity of water and sustainable development of water resources of the region by involving the people and utilizing indigenous knowledge and technology at the same time seems to be urgent need. Upgrading the rainfed agriculture through integrated rainwater harvesting systems and complementary technologies such as low cost pumps and water application methods, such as low head drip irrigation, runoff storage through farm ponds, micro rain water harvesting structures, earth dams etc. are some of the desired interventions. The sustainable livelihood in hills could be achieved by focusing on the improvement of quality of household livelihood by harnessing local resources, which are compatible with the mountainous agro-climatic situation. In general, adaptation in rainfed agriculture
may be brought about by introduction of improved climate resilient crop cultivars, by modifying existing cropping pattern, diversifying the crops, introducing suitable water supply, irrigation, drainage systems and resource conservation technologies. Raised and sunken bed systems help in crop diversification and better water use efficiency. Concerted efforts are required from water harvesting to distribution and application so as to maintain a proper water balance. Efforts are also needed to develop water resources in an integrated manner at basin level to not only sustain agricultural production but also protect the environment and meet the increasing water requirements in other sectors. Watershed as a tool for soil and water conservation (SWC) measures as well as for socio-economic development of community is already a widely accepted fact. The component of the watershed includes socio-economic survey for analysis of resource status, water harvesting structures, construction of bench and half moon terraces along with other agronomic measures for SWC, introduction of HYV crops, fruits and vegetables etc. Increasing scientific and social awareness among the farmers to educate and prepare them to face the consequences of climate change is an integral part of overall adaptation strategy. This may be achieved through effective short/medium term climate predictions and dissemination and introducing suitable and easily accessible microfinance and insurance facilities. Crop diversification, resource conservation practices, adoption of location specific integrated farming system modules, promotion of production and use of organic manures, appropriate low water demanding crop rotation, crop varieties, agro-techniques such as direct seeding, zero tillage, system of rice intensification, low water demanding crops like pulses and oilseeds, adoption and improvements of traditional water management practices etc. are some of the options for consideration in the overall strategy of efficient water management in the region.

References


