DOI: 10.54083/ResBio/4.1.2022/05-20 *Res. Bio.*, 2022, 4(1):05-20

Research Biotica

e-ISSN: 2582-6743
March, 2022

Article ID: RB104 Review Article

Natural Farming - A Sustainable Ecological Approach

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Conflict of interests: The author has declared that no conflict of interest exists.

How to cite this article?
De, L.C., 2022. Natural Farming - A Sustainable Ecological Approach. *Research Biotica* 4(1): 05-20.

Abstract

Natural Farming is a chemical free traditional agro-ecology based diversified farming system which integrates crops, trees and livestock with functional biodiversity. Natural farming increases production, saves water, improves soil health and farmland ecosystems. It is considered as a cost effective farming practices with scope for raising employment and rural development. Types on natural farming includes Fertility farming, Organic Farming, Sustainable agriculture, Agro-ecology, Agroforestry, Ecoagriculture and Permaculture rely on principles of no tillage, no fertilizer, no pesticides or herbicides, no weeding and no pruning depending upon local climate and conditions.

Keywords: Agro-ecology, Agro-forestry, Diversified farming, Ecosystems, Organic farming, Sustainable agriculture

Introduction

Natural Farming is a chemical free traditional farming method. It is called as agro-ecology based diversified farming system which integrates crops, trees and livestock with functional biodiversity. In India, Natural farming is promoted as Bharatiya Prakritik Krishi Paddhati Program (BPKP) under centrally sponsored scheme - Paramparagat Krishi Vikas Yojana (PKVY). BPKP promotes traditional indigenous practices which reduces externally purchased inputs. It is mainly based on on-farm biomass recycling with major emphasis on biomass mulching, use of on-farm cowdung-urine formulations, periodic soil aeration and exclusion of all synthetic chemical inputs. The BPKP program has been adopted in the state of Andhra Pradesh, Karnataka, Himachal Pradesh, Uttar Pradesh, Gujarat and Kerala. Natural farming increases production, saves water, improves soil health and farmland ecosystems. It is considered as a cost effective farming practices with scope for raising employment and rural development. It is estimated that around 2.5 million farmers in India are already practicing regenerative agriculture. In the next five years, it is expected to reach 20 lakh hectares. In any form of natural farming of which 12 lakh ha are under BPKP.

Natural farming also referred to as "the Fukuoka Method", "the natural way of farming" or "do-nothing farming", is an ecological farming approach established by Masanobu Fukuoka (1913-2008). Fukuoka, a Japanese farmer and philosopher, introduced the term in his 1975 book '*The One-Straw Revolution*'.

The system works along with the natural biodiversity to encourage the complexity of living organisms - both plant and animal - that shape each particular ecosystem to thrive along with food plants. Fukuoka found farming both as a means of producing food and as an aesthetic or spiritual approach to life, the ultimate goal of which is "the cultivation and perfection of human beings" (Floyd and Zubevich, 2010; Paul, 1990). He suggested that farmers can get could benefit from closely observing local conditions (Colin, 1996). Natural farming is a closed system, one that demands no human-supplied inputs and mimics nature and to take advantage of local environment (Morse and Stocking, 1995). He claimed that his approach prevents water pollution, biodiversity loss and soil erosion, while providing ample amounts of food, and there is an improvement of scientific work in fields like agroecology and regenerative agriculture, that lend support to these claims (Hilmi, 2018; Reddy, 2010). In Natural farming, decomposition of organic matter by microbes and

Article History
RECEIVED on 15th December 2021 RECEIVED in revised form 03rd February 2022 ACCEPTED in final form 05th February 2022

earthworms is encouraged right on the soil surface which gradually adds nutrition in the soil over period.

Types of Natural Farming

- Fertility farming
- Organic Farming
- Sustainable agriculture
- Agro-ecology
- Agroforestry
- Ecoagriculture
- Permaculture

Fukuoka's Principles

Fukuoka classified Natural farming into five principles (Norberg-Hodge *et al.*, 2001):

- No tillage
- No fertilizer
- No pesticides or herbicides
- No weeding
- No pruning

Principally Natural farming minimizes human labour and adopts nature production of foods such as cereals, fruits, vegetables and ornamentals in biodiverse agricultural ecosystems. Seeds are germinated without plowing on the surface depending upon conditions of microclimate. Fukuoka mentions that the ground remains covered by weeds, legumes along with grains, vegetable crops and orchards. Chicken roam in orchards freely and ducks and fishes populate rice fields. Usually ground cover enhances nitrogen fixation. Straw from the previous crop mulches the top soil. Each grain crop is sown before the previous one is harvested by broadcasting the seed among the standing crop. It makes a densier crop smaller but highly productive and stronger plant (Fukuoka, 1987). Natural farming considers soils as a fundamental natural asset. Ancient soils possess physical and chemical attributes that render them capable of generating and supporting life abundance. It can be argued that tilling actually degrades the delicate balance of a climax soil. Experimental evidences suggest that the reduced tillage preserves the crop residues on the top of the soil, allowing organic matter to be framed more easily and hence increasing the total organic carbon and nitrogen which subsequently increase aerobic, facultative anaerobic and anaerobic populations (Sylvia *et al.*, 1999). Fukuoka advocated avoiding any change in the natural landscape through creation of terraces on slopes to control soil erosion by simply growing trees and shrubs on slopes.

Yoshikazu Kawaguchi's Natural Farming

He is the founder of Akame Natural Farm School and restates the core values of Natural farming as:

- Do not plow the fields.
- Weeds and insects are not considered as enemies.
- There is no need to add fertilizer.
- Growing of foods are adjusted based on local climate and conditions.

His principles were based upon the philosophy of *Final Straw: Food, Earth and Happiness*.

Fertility Farming

In 1951, Newman Turner advocated the practice of 'Fertility Farming' a system through the use of a cover crop, no tillage, no chemical fertilizer, no pesticides, no weeding and no composting. He also suggested a natural method of animal farming.

Organic Farming

Improper farming practices such as monocropping, imbalanced fertilization, poor soil organic matter management, soil contamination, soil compaction, mining of soil nutrients, water logging, depletion of ground water, decline in soil biodiversity and changing pest and disease complex and application of imbalanced NPK fertilizers ratio of 7.9:3:1 as against normal values of 4:2:1 are the major factors for soil degradation.

Organic farming is the system of production that depends upon the animal manures, organic wastes, crop rotations, legumes, pest control through biological means. It does not allow the use of synthetically produced fertilizers, pesticides, growth regulators and livestock additives. It is the ecological production management system that promotes and enhances biodiversity, biological cycles and biological activities of the soil. The essence of organic farming is to make the soil capable of supplying all the essential nutrients to the crop for its proper growth and development. Organic farming sustains and enhances productivity by improving the soil health and agro-ecosystem. Recently, organic food production is gradually gaining momentum worldwide relying upon the minimal cost of farm inputs and management practices that restore, maintain and sustain ecological harmony. In the organic crop production system, it is found that there is yield drop during the conversion period as it needs certain time for the soil and plants to reach equilibrium. Yield of crops may attain to the satisfactory level once the systems get established. To sustain fertility and productivity of Indian soils there is urgent need to promote liberal application of organic manures by the farmers. India is blessed with various types of naturally available organic form of nutrients but quality of these inputs needs to be improved through Integrated Nutrient Management (INM), Integrated Pest Management (IPM) and Integrated Weed Management (IWM) systems. Integrated Farming Systems make a linkage between organic farming and intensive agriculture (Singh, 2001).

India has brought 4.72 million ha under organic certification processes, including 0.6 million ha of cultivated agricultural land and 4.12 million ha for wild harvest collection in forests, as of March 2014. Sikkim has become India's first fully organic state by implementing organic practices on approximately 75,000 ha of agricultural land. Institutional support for organic production was created by the launch of the National

Program for Organic Production (NPOP) by the Agriculture and Processed Food Export Development Authority (APEDA), Ministry of Commerce. The NPOP supports promotional initiatives, accreditation of inspection and certification agencies, and offers support to agri-business enterprises to facilitate export. APEDA has been interacting with the European Union (EU), the United States Department of Agriculture (USDA), Japan, and IFOAM for recognition of equivalence of the Indian quality assurance system.

Major destinations for organic products from India are the U.S., the EU, Canada, Switzerland, Australia, New Zealand, South-East Asian countries, West Asia, and South Africa. Soybean comprised 70% of the commodities, and products exported followed by cereals and millets other than basmati rice (4%), sugar (3%), tea (2%), pulses and lentils (1%), dry fruits (1%), and spices (1%).

Organic farming is growing rapidly among Indian farmers and entrepreneurs, especially in low productivity areas, rain-fed zones, hilly areas, and the north-eastern states, where fertilizer consumption is less than 25 kg $ha^{-1}year^{-1}$. Nine states in India have promoted policies and programs on organic farming. Uttarakhand has made organic a thrust for improving its mountain agriculture farm economy and livelihood. Mizoram and Sikkim declared their intentions to move to total organic farming. Karnataka has formulated organic policies, and Maharashtra, Tamil Nadu, and Kerala have supported public-private partnerships for the promotion of organic farming.

There are the four principles of organic farming namely Principle of health, Principle of Ecology, Principle of fairness and Principle of care. Major advantages of organic farming are nutritional, poison free and tasty food, low growing cost, enhancement of soil nourishment, more energy efficient, more carbon sequestration, less water pollution and ecofriendly practices.

Important steps for organic production include:

• 1-3 years conversion period.

• Farm designing with the cattle shed, compost yard, storehouse, multipurpose border trees, fodder shrubs, grasses and legumes and farm diversification by keeping apiculture, dairy farming *etc*.

• Land management with well decomposed FYM @ 10-15 t ha^{-1} or vermi-compost @ 2-5 t ha^{-1}.

• Choice of crops and varieties which are naturally resistant to insect pests and diseases.

• Nutrient management with organic recycling, enrichment of compost, vermicomposting, animal manures, urine, farm yard manure, litter composting, use of botanicals, green manuring *etc*. Biofertilizers like Azolla, Azospirillium, Azotobacter, Rhizobium culture, PSB, saw dust, calcified seaweed, limestone, gypsum, chalk, magnesium rock and rock phosphate, liquid sprays *etc*.

• Weed management manually or with rotary weeder and practice of intercropping, mulching, crop rotation and growing of cover crops.

• Soil and water conservation with mulching, preparation of half-moon terraces, bench terraces, contour bunding, planting of double row of herbaceous fruits crops across the slope and fruit trees on the contour line, use of drip irrigation system for high value fruit crops and construction of water storage tank (Jalkund).

Indigenous Technical/ Traditional Knowledge (ITK)

Indigenous Technical/ Traditional Knowledge (ITK) is an accumulated intimate knowledge of farmers environment comprising land, water, tree, plants, animal *etc*. and they have found solutions to manage the problems by taking series of decision and implementing them by allocating resources in efficient manner. This knowledge consists of many facts and helped them to evolve many practices which have been tested over long periods of time and proved beneficial. They depend entirely on locally available resources and knowledge base for maintaining productivity of crops and livestock. In the modern developmental efforts, knowledge of such indigenous practices provides valuable inputs to make efficient use of natural resources. Such components can be incorporated for the development of sustainable farming system and practices (De, 2021).

• Cucurbit seeds are kept embedded in fresh cow dung ball which then buried deep in soil for better germination (Musara and Chitamba, 2014).

• In desert areas, Chickpea is sown behind camel drawn plows in sand dune area.

• Cut ends of sugarcane sets are plastered with a mixture of honey, ghee, the fat of hogs and cow dung.

• In Rajasthan, soil fertility is renewed by using FYM (cowdung, sheep, goat and camel faecal pellets), wood ash, animal urine, growing nitrogen fixing leguminous crops intermixed/ intercropped with cereals/ oilseeds, allowing certain local weeds and xerophytic plants *viz*. bui (*Kochia indica*), fog (*Caligonum polygonoids*), Kheinp (*Crotalaria burhia*), bordi (*Zizyphus manuritiana*) to grow undisturbed and maintaining adequate khejri (*Prosopis cineraria*) tree population (8-12 trees ha^{-1}) in the field.

• Ancient Tamil test widely quoted the use of *Calotropis gigantea*, *Morinda tinctoria*, *Thespesia populnea*, *Jatropha gossypifolia*, *Ipomoea* spp. and *Adhatoda* spp. to be used as green leaf manure. Ancient agriculturists relied on crop rotation and intercropping to restore soil fertility. Fauna including ants, earthworm and frogs were used to improve soil physical properties. Composting practices have also been documented in ancient literature on ideal farming practices.

• In Sikkim, rotten forest litter or organic matter rich top soil is used to put into grooves or rock over potato seed or farmers use forest litter as bedding material for compost production.

• In Nepal, farmers bury dead animal and use toilets as an integral part of soil fertility management.

• In Karnataka, Vetiver grass (*Vetiveria zizanoides*) is planted along farm boundaries and bunds to conserve soils. Ancient

dynasties from Mauryans to Mughals evolved various systems for soil water management such as anicuts, earthen dams, field bunds, checks dams, canals, tanks, pound wells and reservoirs.

• In Gujarat, the most common practices followed by the farmer to conserve soil moisture are summer tillage, field boundary bunds with vegetative cover and intercultural operations. In Arunachal Pradesh, Farmers protect springs from flooding and encroachment of livestock. They maintain water sources by using locally available materials mainly stone, wood, bamboo, soil *etc*.

• In the hills, natural perennial streams are the main source of water for domestic and irrigation uses. The drip irrigation using bamboo is practiced by farmers in Jaintia hills of Meghalaya to irrigate arecanut and betelvine grown on steep hill slope with bouldary soil.

• In Sikkim, rice and maize cultivation on terraces are practiced since long time. This method controls surface run off and prevents rill formation and controls the advancement of already existing gullies.

• In some parts of Rajasthan (Jaipur, Sikar), farmers use smoke from mixture of half-dried cowdung + shell of peahen egg + dried cow horn to control fruit rotting and fruit dropping in cucurbits, chilli and mango.

• To check frost damage in chickpea and mustard, crop dried parts + straw is half burnt near crop boundary to create smoke during night.

• A rope is passed over the chickpea crop in the early hours of day to disturb the dew which in turn to check the frost damage.

• In paddy, spray with a solution of cowdung prepared by mixing 3 kg cowdung in 3 litres of water was effective against the control of paddy blast and bacterial blight.

• In case of bunchy top disease in chillies, dusting of ash, spray of butter milk, spray of liquid waste of tanned leather and spray if cow/ goat urine was recorded in the tribal areas.

• Some farmers used to apply fresh cowdung near the collar region of chilli to control fungal disease *viz*. damping off and dieback.

• In case of soil diseases, root rot, collar rot, the castor cake, karanj cake or neem cake were used as control measures.

• The milk solution (1 litres milk in 9 litres of water) is effective to control powdery mildew and viral diseases.

• 20 kg of *Casuarina equisetifolia* leaves boiled in water for 20 min. After cooling, the solution should be filtered. Then the extract will be diluted with water and can be given to control some bacterial and fungal diseases.

• The wheat seeds are soaked in the milk before sowing to avoid diseases.

• Prepare solution from 2 kg fresh leaves of papaya in 3 to 4 litre of water and keep it overnight. After filtration, this is diluted with 50-60 litres of water and 250 ml soap solution added to it, is effective to control brown spot disease of paddy.

• Cultivation of marigold followed by solanaceous vegetable crop is effective to control bacterial diseases.

• Leaves of Khair (*Acacia catechu*) can be put into water channel to control brown spot disease of paddy.

• Application of wood or cowdung ash on foliage of vegetables *e.g.*, Chilli, Onion and Cucurbits to prevent insects such as thrips and aphids is a common practice.

• 4 kg tobacco leaves and twigs are boiled in 40 litres of water for 40 min. After cooling, one kg soap powder is mixed and solution is diluted 7-8 times and sprayed to control aphids and white files in kinnow and other citrus plants.

• Smoke created by putting sulphur over hot cowdung has been reported to kill/ repel aphids and other sucking pests of mango.

• Maize seeds are soaked in cow urine for 10-12 hours before sowing. According to farmers, this treatment increases resistance against insect pests.

• Rice seedlings raised from seed treated with extract of neem kernel are resistant to leaf hopper.

• In paddy, spraying a solution of 4 litre of cow urine and 10 g asafoetida in 10 litres of water repel aphids and jassids.

• For prevention of infestation of shoot borer in mango tree, common salt is mixed with soil near the collar region of tree.

• In case of insect holes made by shoot borer and bark eaters in mango, jiggery is placed in the holes to attract other predators so that they kill feed upon the insert present in the hole. Similarly, the practices of pouring Kerosene or Petrol in holes and blocking holes with mud or cowdung are also common in citrus plants.

• In Arunachal Pradesh, farmers believe that the use of cowdung slurry can protect crops from aphid attack and as repellent to cutting and biting insects and animals. Cattle urine has successfully used against thrips, mites, aphids and caterpillars. Application of extracts prepared from the parts Sisnu (*Urtica* spp.) and fruits of Timuz (*Zanthoxylum armatum*) plants are used to control many kinds of chewing, biting and cutting insects. Leaf and leafy extracts of Chinese berry (*Melia azadirachta*) controls various kinds of insects.

• In Arunachal Pradesh, Padam Minyong Adi society observes different rituals when field crop is attracted by pests' diseases. In one of the rituals, an alter is erected by using small branches of selected trees, leaves of Talo, Kow, and bamboo tumbler in one of the corners of the field. Near the altar, 10-15 big containers of Apong (a local drink), sufficient quantity of rice, small pieces of fresh cut ginger and one red coloured cock are offered to Goddess of crops of kine-nane. The Adis of pasighat area perform another ritual Irrii whenyoung paddy plants just grow up. Likewise, the Galo-Adi society performs Ampu-yolu ritual for the protection of their crops from pests and diseases. The Adi tribes of Basar, West Siang District, Arunachal Pradesh offer four worship during the Kharif season:

➢ *Dibin*: Worship (Puja) after sowing of paddy for better germination .This worship is done during the moths of

February-March. During the worship day poultry birth are offered to the Goddess and no one enters the paddy field on that day. It is believed that the person who will enter the field on that day, his crop will not perform better.

➢ *Tachi*: Worship for control of pests in maize. This is done in the month of May-June. Pigs or poultry birds are sacrificed to Goddess and there is a ban to enter the field on that day.

➢ *Ampu*: This is an important worship of Adi tribes of Arunachal Pradesh. It is done to control the insect-pest problem in Jhum rice as well as wet land rice. It is done for two days. During these two days, no one enter the crop filed. Sacrifice of pig is a must in this worship.

➢ *Mari*: This is the worship of Goddess Laxmi after the harvest of the paddy crop. This is done in the months of November–December. Like Ampu sacrifice of pig is compulsory in this puja.

• Green gram can be kept free from any pest infestation by treating with 1% neem leaf powder.

• Leaves of lakki (*Vitex negundo*) are incorporated in any pulse seeds for long time preservation.

• There is a common practice of storing food grains in wheat or barley straw to prevent storage pest damage.

• A layer of sand (5-7 cm) is effective to protect pulses from beetle attack.

• Pulses mixed with little cowdungs powder in earthen post can be stored for long time.

• Seed mixed with *Acorus calamus* (Baje) powder in the ratio of 10:1 kg, respectively would help in preserving the seeds free from stored pests for long time.

• Milled chickpea, green gram and others pulses are stored after thoroughly treated mustard oil.

• In Rajasthan, garlic leaves are used for safe storage of food grains.

• Fishing is an exotic origin among Adis of Arunachal Pradesh. There are altogether 32 different fishing techniques adopted by tribes only. Out of them, Hib Rinam is more harmful to aquatic life. Rilen Minnam, Hibok Pena, Hill Monam and Hibok Tumnam are harmful and Likam Panam, Liru Hinam, Ngou Paanam and Ngoi Tumnam are harmful. Other techniques are completely harmless to aquatic life.

• In most of the fishing techniques, herbal poisons are used, they have short lived effects in comparison to chemical.

Traditional Additives for Organic Agriculture

Traditional additives comprises of bulky organic manures mainly Farm Yard Manure (FYM) for improvement of soil total nitrogen (Bharadwaj and Guar, 1985); compost which can be prepared from crop residues, weeds and vegetative biomass, sugarcane trash and pressmud, coir waste, tea waste; green manures obtained from sunhemp, *Sesbania aculeata,* cowpea, cluster bean; sewage and sludge from cities and towns; sheep, goat and poultry manure; concentrated organic manures *viz*. oilcakes like castor cake, karanj cake, cotton seed cake, mahua cake, safflower cake, groundnut cake, linseed cake, rapeseed cake and sesame cake; meat meal, blood meal and fish meal which have adequate amounts of NPK (0.5-2.0% N, 0.2-1.0% P_2O_5 and 0.5-2.0% K_2O) and higher C:N ratio.

Organic Sources and Their Role

The potential organic sources of plant nutrients are green manure crops, crop rotation, crop residues, organic manures, FYM, Night soil, sludges, oilcakes, blood meal, compost, phospho-compost, vermin-compost, biogas slurry, agricultural wastes, press mud, biodynamic preparations, biofertilizers *etc*. (Sharma, 2004) (Table 1). Organic sources improve soil structure, soil aeration, water holding capacity and reduce soil losses due to erosion. They supply nutrients in a balanced ratio and stimulate soil flora and fauna.

Table 1: Organic sources for essential elements (De *et al.*, 2007)

Essential elements	Sources
Phosphorus (P)	Poultry litter, rock phosphate
Potassium (K)	Cover crop, mined granite, basalt, feldsper
Calcium (Ca), Magnesium(Mg) and Sulphur (S)	Sea weed extracts, dolomite, gypsum, limestone, crab shells
Micronutrients (B, Cu, Fe, Mn, Mo and Zn)	Liquid sea weed extracts, rock powder

1 ton green leaf manure = 10 kg of urea; Optimum dose of green biomass = 4-5 tonnes ha^{-1}

Important Organic Substrate Media for Ornamental Plants

Cocopeat

Cocopeat is a multi-purpose growing medium made out of coconut husk. The fibrous coconut husk is prewashed, machine dried, sieved and made free from sand and other contaminations such as animal and plant residue. Cocopeat is a very good alternative to traditional peat moss and Rock wool. It has air filled porosity and high water holding capacity and is an ideal growing medium for the plant crops. It is 100% organic and ecofriendly, free from soil borne pathogen and weed. It has a pH of 5.7-6.5, EC level < 1 mS cm^{-1} is ideal for plant growth.

Vermiculite

This is a micacious mineral produced by heating to 745 °C. These are expanded plate like particles having very high water holding capacity, aeration and drainage. Vermiculite is hydrated aluminium iron magnesium silicate material with accordion like structure. It has a very low bulk density, a neutral pH, a high CEC and small amounts of potassium and magnesium. It is well suited for propagation media.

Perlite

This is a siliceous mineral of volcanic origin. Perlite is rigid, sterile and essentially infertile with minimum CEC and neutral pH. Perlite may be included in the mix to increase aeration and to lower bulk density. It is generally recommended for use in a propagation media.

Rock Wool

It is produced by burning a mixture of coke, basalt, lime stone and slag from iron production at 1600 °C temperature. The fiber rock wool is available in cubes and slabs. It is non-biodegradable, pH is 7 to 8.5, no buffering capacity, contain calcium, magnesium, iron, manganese, copper and zinc, CEC is negligible, does not require pasteurization, light is weight, high water holding capacity and good aeration.

Peat

It is the common component of artificial growing media. Peats are composed of several species of plant including mosses, sedges and grasses. In a growing medium, the value of peat is determined by the type of plant material and degree of decomposition. Peats are classified into four categories *viz*., Hypnaceous moss, Reed and Sedge, Humus or Muck and Sphagnum Moss.

Humus or Muck

These peats are the decomposed debris of finely divided plant materials of unknown origin. It contains sufficient quantities of silt and clay particles and does not improve drainage or aeration. Humus is not recommended for use in growing media due to its rapid decomposition and particle size.

Sphagnum Peat Moss

This is the dehydrated remains of acid bog plants from the genus Sphagnum. It is low in soluble salts, long lasting in the mixture, uniform in the composition and improves drainage and aeration. Sphagnum peat moss has a good water holding capacity, high CEC, low nutrient levels and a comparatively low pH (3.0-4.5). It is the most desirable form of organic matter for the preparation of growing media.

Bark

These are by-products of the pulp, paper and plywood industries. Hardwood bark is the common ingredient of a growing medium. Bark is aged with lime and leaching to reduce the risk of toxicity of plants. Hardwood bark along with nitrogen makes a good potting media. Soft wood bark is acceptable but it lowers the pH of a media and so, liming is required. Barks are lighter in weight, sterile and have capacity to retain water as well as to drain the same.

Vermicompost

It is prepared from the organic wastes upon the action of earthworms. It contains 2.5-3.0% Nitrogen, 1.0-1.5% Phosphorus and 1.5-2.0% Potash.

Vermiwash

It is washings from the earthworms collected during the preparation of vermin-compost, used as spray in raising of nursery, lawn and orchids (Ismail and Pramoth, 1995). Vermiwash is rich in growth promoting substances.

FYM/ Compost

It is prepared from the decomposition of organic wastes through anaerobic organisms. It contains fair amount of macro and micro-nutrients and most commonly used organic supplement given to the flower crop cultivation. FYM contains 0.5-1.5% N, 0.4-0.8% P_2O_5 and 0.5-0.9% K_2O whereas Garden compost contains 0.5% N, 0.3% P_2O_5 and 0.8% K_2O.

Coconut Water/ Liquid Manures

Tender coconut water contains growth promoting substances such as cytokinin which is reported to increase vaselife of cut flowers and is also used in the tissue culture media. Liquid organic solution made from leaf (ground fern + *Artemisia vulgaris*) and rotten cowdung manures are rich in various anions and cations and used as foliar spray for cultivation of commercial flowers.

Saw Dust

This is a by-product or waste product of wood working operations such as sawing, sanding, milling and routing. It is composed of small chippings of wood. It is ideal for propagation.

Use of Organic Substrate in Floriculture (De *et al.*, 2016)

- As substrate media
- As a component in plug plant production
- In preparation of nursery for flower seeds
- As a component for pot mixture for foliage plants
- As important media for greenhouse crops to improve the soil physical properties
- As a soil drench of bulb soaking or foliar spray
- In propagation of ornamental crops
- In the hardening of tissue cultured plants
- As a plant protection

Organic Substrate Media for Growing Various Flower Crops

Compost, garden soil, carbonized rice hull, coir dust, saw dust, fine sand, poultry manure and other organic materials are used as potting materials for various ornamentals (Table 2). Potting media should be sterilized in boiling water, solar irradiation or by burning or heating before planting to control soil borne diseases.

Biofertilizers

These are ready to use live formulates of beneficial microorganisms which on application to seed, root or soil fix atmospheric nitrogen or solubilize/ mobilize plant nutrients or otherwise stimulate plant growth substances. These free living or symbiotic microorganisms directly or indirectly contribute nutrition to crop plants. Free living organisms fix nitrogen without any association with any other organisms *e.g.*, *Azotobacte*r. Symbiotic association such as Legume-Rhizobium symbiosis and Anabaena-Azolla symbiosis expresses the mutual beneficial partnerships between the two organisms. Associative symbiotics fix nitrogen in C4 plants and the organisms responsible for this process is *Azospirillum*. Based on type of microorganisms, the biofertilizer can also be classified as Bacterial biofertilizers (*Rhizobium*, *Azospirillum*, *Azotobacter*, *Phosphobacteria*), Fungal biofertilizers (Mycorrhiza, Algal biofertilizers (Blue Green Algae, Azolla), and Actinomycetes biofertilizers (Frankia). Legumes on an average contribute 50-200 kg N

Table 2: Organic substrate media for growing various ornamentals (De, 2013; Kumar and De, 2007)

Name of Ornamentals	Substrate Media
Rooted cuttings	Sand, loam, leaf mould
Hard wood plants	Sand, loam, peat moss, leaf mould, humus, cowmanure
Rose	Cowdung, loam, sand
Bulbous ornamentals	Cowdung, loam, sand, leafmould, charcoal
Terrestrial orchids	Leaf mould, sand, caly soil, bone meal, saw dust, wood charcoal dust, wood shavings, manures
Epiphytic orchids	Charcoal, brickpieces, sphagnum moss, tree bark
Anthurium	Coirpith, coarse sand, brick pieces/ tiles, sugarcane baggase, leaf mould, rockwool, sawdust, tree barks, wood shavings, poultry manures
Gerbera	Sand, coir pith/cocopeat, leaf mould, FYM, vermicompost
Foliage & potted plants	FYM, sand, leaf mould, cocopeat, Charcoal
Carnation	Peat moss, perlite, sand
Lilium	Agropeat, vermicompost
Chrysanthemum	Cocopeat, garden compost
Cymbidium orchids	Cocochips, cocopeat, brick pieces, vermiculite, osmocot, dry leaf fern, leaf mould
Dendrobium orchids	Cocochips, brick pieces, tree barks, wood chips, leaf mould
Vanda orchids	Cocochips, brick pieces, tree barks, dry leaf fern
Phalaenopsis orchids	Cocochips, brick pieces, leaf mould, green moss, sphagnum moss
Oncidium orchids	Cocochips, brick pieces, leaf mould
Cattleya orchids	Cocochips, brick pieces, leaf mould, dry leaf fern

ha^{-1} whereas biofertilizers containing microorganisms like *Rhizobium*, *Azotobacter*, *Azospirillum*, Blue Green Algae, Azolla may contribute 40-60 kg N ha^{-1} and P-solubilizers may add 20-30 kg P_2O_5 ha^{-1}. *Azospirillum* excretes growth promoting hormone (IAA) which results in more root biomass. It promotes uptake of nutrients like NO_3, NH_4, H_2PO_4, K and Fe. In flowers and ornamental plants, seedlings are treated with 1.5-2.0 kg Azospirillum inoculants per hectare for getting beneficial effect. Azotobacter is well known to synthesize IAA, Gibberellins and B-vitamins and it has fungistatic properties. In flowers, seedlings treated with 1.5-2.0 kg Azotobacter inoculants per ha whereas bulbs/ tubers are treated with 3.0-4.0 kg ha^{-1} for getting better effect.

Vermicomposting

Vermicomposting is a biotechnological process by which earth worms are used to convert organic materials (usually wastes) into a humus-like material known as vermicompost. The African species of earthworms, *Eisenia fetida* and *Eudrilus eugenae* should be selected are ideal for the preparation of vermicompost. Only plant-based materials such as grass, leaves or vegetable peelings should be used in preparing vermicompost.

• Materials of animal origin such as eggshells, meat, bone, chicken droppings, *etc*. are not recommended for preparing vermicompost.

• Gliricidia loppings and tobacco leaves are not prescribed for rearing earthworms.

• The earthworms should be protected against birds, termites, ants and rats.

• Adequate moisture level should be maintained during the process. Either stagnant water or lack of moisture can hamper the earthworms.

• After completion of each process, the vermicompost should be removed from the bed at regular intervals and replaced by fresh waste materials.

• Vermicompost can be used for all crops: agricultural, horticultural, ornamental and vegetables at any stage of the crop growth.

• For general field crops about 2-3 t ha^{-1} vermicompost is used by mixing with seed at the time of sowing or by row application when the seedlings are 12-15 cm in height. Normal irrigation is given.

Integrated Plant Nutrition System (IPNS)

Integrated Plant Nutrition System (IPNS) is a holistic approach to plant nutrition by obtaining the nutrients from both inorganic and organic sources to maintain and sustain soil fertility and increase crop productivity in a framework of an ecologically compatible, socially acceptable and economically viable manner. The principles are basic soil fertility and climate, nature of crop in cropping system, at least 30% of the total nutrient levels NPK in organic form. The major themes under IPNS are importance of plant nutrients for meeting the agricultural production requirements, soil organic matter, biomass, soil microflora and management of integrated plant nutrient system, renewable supply of plant nutrients from natural sources and plant nutrient transfer to

crops, place and role of local and external sources of plant nutrients in cropping systems and their evaluation, plant nutrient management in farming systems and watersheds. Suitable organic materials for IPNS are plant residues (crop residues, green manure), animal wastes (Animal manure Slaughter house wastes), compost (wastes of both plant and animal materials including city garbage), biofertilizers **(**Blue Green algae, Rhizobium, Azotobacter, Azospirillium), organic sources (Rural and Urban compost), crop residues (Rice, straw, corn stover, vegetable residues), green manures (Sunhemp, Dhaincha).

Natural Growth Promoters

Various natural growth promoting and soil improvement substances have been identified, developed and used for promoting crop growth in many crops. These natural preparations will be of much help in conversion from chemical farming to organic farming. Such alternate natural preparations are Panchgavya, Amritpani, Themore, Fish amino acid (FAA), Arappumore, arche-bacterial solution, Egg amino acid, Extended EM solution and treated cow urine (Table 3). These materials are described below:

- Input generation at the site.
- Yield potential equal or better than those obtained after application of optimum does of agro-chemicals.
- Continuous improvement in physico-chemical and biological soil properties.
- Par excellence produce quality with respect to nutrition, appearance and better shelf life.
- Eco-friendly and cost effective technology.

Insect Pest and Disease Management

The pest and disease management in organic farming are heavily dependent on preventive measures rather than curative practices which are based on the ecologically safer management methods. The emphasis has been given to maintain the health of the ecosystem thus enabling plant to become resistance to attack by insect-pests and diseases. Broad management of ecosystem through little modification in the cultural practices such as crop rotation, soil quality management through the addition of organic amendments constitute the preliminary defence against the attack of insect-pests and diseases followed by use of the curative

Table 3: Natural growth promoters for enhancement of soil fertility and crop productivity

Sl. No.	Name of product	Components	Application
1	Angara	Bhomi sanskar is being performed to make the soil fertile, wherein 15 kg rhizosphere soil of banyan tree (*Ficus bengalensis*) ''Vat Krishi'' is broadcasted on acre of land.	It has lot of earthworms and other beneficial microbes, which improves soil fertility under Rishi Krishi Method.
2	Amrit Pani	The composition may be varying in different parts of India. Requirement: Cow's urine: 1 litre Cow's Dung: 1 kg Jaggery (Palm sugar): 250 gms Water: 10 litres	This is known as starter solution for increasing soil fertility and crop yield under Rishi Krishi Method.
3	Panchagavya	Five products from cow viz., cow milk, curd, ghee, dung, and urine traditionally known as panchgavya. Requirement: Cow dung: 5 kg Cow's urine: 5 litres Sour curd: 2 litres Milk: 2 litres Ghee: 2 litres Jaggary: 1 kg Tender coconut: 5-6 nos Banana : 10-12 nos Water: 5 litres	• It stimulates plant growth. • It mitigates micro-nutrients deficiency. • It acts as a pest repellant. • It helps plants to develop resistance against diseases.
4	Themore solution	Requirement: Coconuts: 10 nos Sour butter milk: 5 litres	• It stimulates plant growth. • It acts as a pest repellent. • It gives good resistance to crops against fungal infection. • During flowering stage, if it is sprayed, it will boost up flowering because it contains lactokinin.

Table 3: Continue...

Sl. No.	Name of product	Components	Application
5	Fish Amino Acid (FAA)	Requirement: Local Fish: 1 kg Palm sugar (Jaggery): 1 kg	• It enhances the growth of plants. • It gives the effect of urea spray.
6	Egg Amino Acid (EAA)	Requirement: Egg: 7 nos Juice of 10-15 nos. lemon fruits Jaggary: 250 gms	It boosts the growth of plants.
7	Organic seaweed extract	Organic seaweed extract is obtained from well-selected naturally grown and cultured marine plants processed under rigid quality control. It also has species seaweed extracts called phycocolloids which contains inherent stickers, natural hormones, amino acids, vitamins, proteins, carbohydrates and rich sea minerals important to plant growth and development.	Organic seaweed extracts make plants green, increase resistance to stress conditions, improve quality of produce and also retard the aging process. More recently it has been demonstrated that in addition to this nutrients (particularly trace element) content seaweed extracts possess compounds which have cytokinin like properties possibly betains are primarily responsible for these beneficial effects of inducing/ improving the crop yield.

methods like use of predators, parasitoids, plant products and ecologically safer chemicals forms the next alternatives of defence against the insect pests and diseases.

Apart from conventional fungicides and microbial biocontrol agents, plant products or extracts have been found detrimental against a wide range of pathogens. Salicylic acid, 2,6-dichloroisonicotinic acid and benzothiadiazole are among such chemicals which induce systemic acquired resistance in plants. Execution of systemic acquired resistance is brought about by the expression of genes coding for pathogenesis related (PR) proteins increase in activity of enzymes such as fenil amonya-liyaz and peroxidase and level of fungitoxic phenols. A number of studies on direct effect of neem leaf and fruit extracts on target pests and pathogens have been reported. Aqueous leaf extract of *Azadirachta indica* induced resistance in barley against *Drechslera graminea* through biochemical changes in the host plant. Chemicals applied in the control of disease pollute the atmosphere and affect the properties of medicinal plants. To avoid the hazardous effects of chemicals, natural products of some plants have been found effective to control the disease. A number of reports are available showing the efficacy of plant extracts especially neem (*A. indica* and *Ocimum sanctum*) showing the antifungal properties.

For ease of understanding and their effective application for management of insect pests and diseases under organic farming, pest and disease management strategies are classified into following categories:

• Modification of cultural practices including crop rotation, soil health management, use of insect resistant plants, *etc*.

• The conservation agronomic practices to restore the natural enemies through provision of hedge rows, shelter belts, *etc*.

• Use of biological control agents such as insect predators, parasitoids, insect pathogens by applying or releasing the agent through inoculate and inundated methods.

• Use of botanicals and their mixtures such as Panchagavya, Dasagavya and mineral oils as curative control measures.

• Use of pheromones and other attractant.

• Use of organic pesticides and other permissible pesticides.

Traditional Ecological Knowledge

This is only through the interaction and relationships with native plants that mutual respect is established (Anderson, 2005).

Rishi Kheti

This method use cow products like butter milk, curd, and its waste urine for preparing growth promoters. The Rishi Kheti is considered to be non-violet farming without any usage of chemical fertilizer and pesticide. Nowadays, this method is practiced by small farmers in M.P., Punjab, Rajasthan, Maharastra, Andhra Pradesh. and Tamil Nadu.

Zero Budget Farming

This is called as Spiritual farming. This method involves mulching, intercropping and the use of several preparations which include cowdung. These preparations are made on site and said to promote microbe and earthworm activity in the soil.

Sustainable Agriculture

It seeks to sustain farmers, resources and communities by

promoting farming practices and methods that are profitable, environmentally sound and good for communities. Five components of sustainable farming are soil management, crop management, water management, disease/pest management and waste management. Three main pillars of sustainable agriculture are environmental, social and economic. Principles of sustainable agriculture includes improving the efficiency in the use of resources, conserving, protecting and enhancing natural ecosystems and protecting and improving rural livelihoods and social well being.

Diversified Farming System is an important tool for enhancement of agricultural growth by promoting food and nutritional security, income and employment generation, poverty alleviation, judicious use of natural resources and ecological environments (Table 4).

Table 4: Main components of organic crop production

Diversification and integration of components	Sustainability	Natural Plant Nutrition	Natural Pest Management
Crop rotation	Crop rotation	Legumes in crop rotation	Diverse crop rotation
Animal manures	Efficient cropping system	Composting	Green manure
Composting	Cover cropping	Cowdung slurry	Cover crops
Intercropping	Intercropping	Green manure	Guard crops
Mulching	Biocontrol	Vermi-composting	Break cropping
Farm scrapping	Mulching	Farm litter management	Use botanical extracts
	Resource conservation	Crop residues management	Weed and pest smothering crop
	Efficient recycling		Fire
			Sanitation
			Tillage
			Biological traps

Alternative Land Use System

Alley cropping systems with growing of crops like legume fodder trees is being recommended to meet food. Fodder and fuel needs besides improving soil fertility. Alley cropping with *Leucaena leucocephala* in upland rice-wheat sequence is beneficial for profitability and soil productivity. Under dry land situations, agroforestry, agri-horticulture, agri-silviculture or silvi-pasture produced a higher benefit: cost ratio compared with arable cropping.

Integrated Farming Systems

Integrated Farming Systems is a well accepted sound strategy for harmonizing joint management of land, water, vegetation, livestock and human resources. It can lead to a quantum jump in sustainable productivity and ensure better livelihood securities to the people. Mixed cropping, intercropping and crop rotation are followed for crop intensification. In rice based cropping systems, legumes are chosen for sustain the soil fertility.

In hill ecosystems, fruit based cropping systems involving intercropping with vegetables, cereals, pulses, roots and tuber crops have been reported for optimum land use and income generation. Vegetative barriers consisting of one or two rows of perennial grasses can be planted across the slope and along the contour. It conserves the soil and checks the runoff. Vettiver, Cenchrus are suitable grasses for the purpose. In dry land ecosystems, crops, dairy, horticulture, poultry, goat rearing, piggery, agroforestry has become indispensable. For coastal areas, with rice and diverse stock of flora and fauna, this system involves growing of fish, prawns, poultry, duckery, piggery, mushroom, bee keeping and horticulture including vegetables. In low land areas, cropping, poultry, fishery and mushroom enterprises can be adopted. In upland areas, the crop component can be integrated with dairy, biogas, spawn and mushroom, apiary, homestead garden, fish rearing and silvi-culture. In rainfed areas, integrated farming system should involve grain crop, fodder crop, fodder trees, perennial grasses and goat rearing.

Jhum Cultivation

It is practiced by the hill farmers to utilize the most of available natural resources to get maximum possible output and to minimize the risks involved in the cultivation by slashing, clearing and burning systems from January-March (Singh and Bag, 2002). Crops grown by the jhum farmers include cereals (rice, maize, millets), legumes (beans, pigeon pea, rice bean, pea, soybean, cow pea), oilseeds (ground nut mustard), root crops (cassava, potato, cococassia, yam, sweet potato), cucurbits (bottle gourd, snake gourd, pumpkin, cucumber, bitter gourd, melons, ridge gourds *etc*.), seeded vegetables (okra, chilli, brinjal, tomato), fruits (banana, papaya, citrus, grapes, local fruits), cash crops (coffee, areca nut) and spices (cardamom, black pepper, large cardamom).

Field Crop Production

In hill region, an alternative form of shifting cultivation can be adopted for adoption of crops such as pulses, upland rice, vegetables, tuber and root crops. Crops like cassava, maize intercropped with soybean, pigeon pea, finger millet, sesame *etc*. can be grown in upper portion of sloppy land while

lower portion can be used for growing rice for production maximization.

Double Cropping of Rice

In NEH region, a pre-kharif rice can be grown with proper adjustment of date of sowing and selection of early varieties like Vivek Dhan-82, Megha Rice-1, VL Dhan 61 before the main crop of rice.

Bun System of Cultivation

This system of cultivation is practiced mainly in the state of Meghalaya. Under this system, the crops are grown on a series of raised beds locally referred to as "Bun" formed along the slope of the hills. Presently, most of the farmers grow crops consecutively for two years in Bun field. In first year, generally tuber crops like ginger, turmeric, potato, sweet potato *etc*. and vegetables followed by upland paddy are grown.

Rice-Fish System of Apatani Plateau

It is a multi-purpose water management system, which integrates land, water and farming system by protecting soil erosion, conserving water for irrigation and paddy-cum-fish culture (Roy, 1986; Chaudhary *et al*., 1993). It has been practiced in a flat land of about 30 km^2 located at an altitude of about 1,525 meter MSL. In the humid tropic climate of Lower Subansiri district of Arunachal Pradesh, Local tribe "Apatani" which develop this system dominates the area. In Manipur and Nagaland Paddy-cum-fish culture is practiced in terraced fields where a small pond is dug in the middle or corner for harvesting of fish during the harvest of paddy. Two crops of fish and one crop of paddy is commonly harvested conserving water throughout the year. Technology intervention of Common Carp found most suitable in the higher altitudes grown with improved rice varieties. In the system, Grass carp is another competent fish commonly grown with rice as pre-*kharif* crop in the plain of Manipur.

Bamboo Drip Irrigation System

The tribal farmers in Muktapur, Jaintia hills district of Meghalaya have developed the indigenous technique of bamboo drip irrigation. Betel vines planted with arecanut as the supporting tree are irrigated with this system, in which water trickles or drips drop at the base of crop. In this system, water from the natural streams located at higher elevation is conveyed with the use of bamboo channels, supports to the site of plantation through gravity flow (Singh, 1988).

Alder based Agriculture in Nagaland

In some pockets of Nagaland the farmers use *Alnus nepalensi*s (Alder) tree for agriculture. In this system the Alder seedlings are planted on the sloppy land intended for cultivation and the alder grows fast till attain six to ten years old. At this stage initially the trees are pollarded, the leaves and twigs are burnt and ash is mixed with soil to prepare it for raising crops such as maize, millets, potato, barley, wheat, chilli, pumpkin, taro *etc*. (Gokhale *et al*., 1985). Subsequently also pollarding is done once every four to six years. Under this process coppice are cut except five to six on top of the main trunk and crop schedule is followed including fallow period of two to four years. The bigger branches stripped of leaves are used for fire wood, while the root of the tree develop nodules (colonies of Frankia) responsible for fertility improvement whereas spreading nature of the roots helps in preventing soil erosion in slopes.

ZABO System

"Zabo" is an indigenous farming system of Nagaland. The word "Zabo" means impounding of water. It has a combination of forest, agriculture and animal husbandry with well founded soil and water conservation base. It has protected forest land towards the top of hill, water harvesting tanks in the middle and cattle yard and paddy fields for storage for the crops as well as for irrigation during the crop period. Special techniques for seepage control in the paddy plots are followed. Paddy husk is used on shoulder bunds and puddling is done thoroughly.

Large Cardamom Plantation in Sikkim

The indigenous tribes *i.e.*, *Lepcha* and *Limbu* used to collect large cardamom from natural forests and domesticate under shade trees like alder. Farmers have evolved a tree cutting schedule to get continuous supply of forest wood and fodder without affecting the shade requirements of large cardamom plants. This tree management system is also helpful in preventing lifting of large cardamom clumps due to thick subsurface spreading roots of old trees. Otherwise, lifting of clumps result into low productivity of large cardamom (Singh *et al*., 1989).

Rattan Cultivation as a Part of Shifting Cultivation

Incorporation of rattan in Jhum Kheti is an indigenous system in Kalimantur, Indonesia. This can be exploited in Jhum areas of Arunachal Pradesh state. These plants are popular as raw materials for furniture industry throughout the world. Arunachal Pradesh alone accounts for 4 genera and 17 species. The genus *Calamus* has the largest number of 12 species followed by *Plectomia*, *Daemonorops* and *Zalacca* (Singh, 2001).

Agro-Horticulture

Raising of annuals crops or vegetables in orchard areas during establishment periods.

Agro-Silviculture

Intercropping with trees and shelter belts.

Silvi-Pastoral

Growing fodder trees/ shrubs in crop lands and pasture, pasture under forest tree plantation.

Agropastoral

Integration of grass lands with production of staple foods.

Rice-Fish-Farming

Fast growing shallow water adapted fish species are raised in the perimetric canal/ trench made around paddy fields.

Livestock-Agriculture-Fish Farming

Fishes are raised in pond enriched with livestock waste and nutrient rich water is used for irrigation. Decomposed layer

of bottom of pond is used for fertilizing field crops.

Poultry-cum-Fish Farming

Poultry is raised on fish pond to utilize droppings for fish culture.

Duck-cum-Fish Farming

Ducks are reared on ponds to utilize waste or droppings for fish production.

Pig-cum-Fish Farming

Piggeries are built on slopping alongside the embankment of pond to utilize waste for fish culture.

Vegetables-cum-Fish Farming

Vegetables are raised along side the pond embankment.

Horticulture-cum-Fish Farming

Fruit trees are raised along the embankment of fish pond or fishes are cultured in drainage channels of horticultural plantations of wet lands.

Poultry-Rice-Vegetable-Fish Farming

Poultry is kept on fish pond so as to utilize their droppings for fish culture. Ponds are drained after build up of organic matter and the bed is used for rice production and side of bed for vegetable production.

Agri-Horti-Apiculture-Duckery-Poultry-Mushroom-Fish Farming

Filed crops, vegetables, horticulture, floriculture, duckery, poultry, mushroom, apiculture *etc*., is integrated with fish culture.

Rice-Poultry-Mushroom-Fish Farming

Fish farming is integrated with staple food, oilseeds, poultry and mushroom.

Waste Land Farming System

Jatropha (*Jatropha curcas*) is a potential crop in the NEH region which can thrive from winter months through mulching. The organic matter from shed leaves aid in the build up of the fertility of the soil.

Horticulture based Farming Systems

Suitable land use systems such as Agrihorti, Agri-horti-silvi pastoral, mixed horti, pure horti, horti-silvi-patoral and multi-tier horticulture system should be developed based on agroclimate zones, crop priority, topography and socio-economical factors.

(a) Agri-Horticulture Land Use System

• 2/3rd area (upper side) is covered under horticultural crops.

• 1/3rd area under cereals.

• Fruit trees are planted in half moon terraces on contour (Triangular system).

• Pineapple should be planted to protect the contour bunds.

• Interspaces in contour should be utilized for intercropping.

(b) Agri-Horti-Silvi-Pastoral (Model Land Use)

• Middle 1/3rd area for horticultural crops.

• Upper 1/3rd for fodder trees.

• Lower 1/3rd for growing cereals and fodder crops.

• Terrace risers are used for growing fodder grass.

(c) Mixed Horticultural Land Use

• Only different horticultural crops are grown.

• The upper 2/3rd area is planted with fruit crops.

• The lower 1/3rd terraced area is planted with vegetable crops.

(d) Pure Horticultural Land Use (Fruit Crops only)

• If the available land is more.

• Suitable for fruit growing.

• The land collectively acquired/ cooperative land can be used for this purpose.

(e) Horti-Silvi-Pastoral System

The horti-silvi-pastoral system has great potential to provide a sustainable land use system, which would maintain an acceptable level of production of fruits, vegetables, fuel wood, timber, fodder *etc*. and at the same time, conserve the basic resources (mainly soil) on which production depends. This system was found economically viable and socially acceptable alternative to *jhuming* in this region.

(f) Multi-Tier Horticultural System

• Horti-horti three-tier system: arecanut + black pepper + ginger/ turmeric/ pineapple/ Assam lemon.

• Silvi-horti three-tier system: MPT + black pepper + ginger/ turmeric/ pineapple.

• Silvi-horti two-tier system (Parkia and pineapple or subabool and pineapple).

• Alder based farming system of Nagaland (alder and vegetables like potato, cole crops or alder and cereals like maize, rice *etc*.

• Alder based large cardamom system of Sikkim.

• MPT + Assam lemon.

(g) Seed Potato based Cropping System

Seed potato is followed by maize, peas, finger millet, soybean and fallow.

(h) Fruit Crop based Cropping System

Ginger, maize, turmeric, leguminous or non-leguminous vegetables and pulses are grown as intercrops along with fruit trees mainly mandarin, guava, papaya, plum, peach, pear and apple.

Agroecology

This is the study of ecological processes applied to agricultural production systems. It is the study of interactions between plants, animals, humans, and the environment within the agricultural systems. It would be organic, regenerative, integrated or industrial, intensive of extensive agriculture. The system properties of agro-ecosystems include productivity, stability, sustainability and equitability.

Agroforestry

Agroforestry is a dynamic and ecobased natural resource management practice through integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefit. Agroforestry farming systems are means of increasing and sustaining agricultural productivity as a source of essential food, fuel wood, fodder and building material and as a supplementary source of income that buffers instability in agriculture income. Traditional agroforestry systems include jhum cultivation, taungya cultivation, trees on farm lands, agri-silviculture, shelterbelts, silvi-pastoral systems, trees on farm boundary, home gardens, plantation crops or commercial agroforestry systems. Trees incorporated in farming systems have the following benefits:

• They provide marketable products such as timber, building poles, firewood, animal fodder, fruits and medicines to earn extra income.

• They improve soil fertility by fixing nitrogen from the air and recycling nutrients from the soil and thereby increase crop yields.

• They help to hold moisture during hot winds during summer, reduce soil erosion and downstream flooding.

• They provide a sustainable source of wood and building materials.

• They serve as live fences in semi-arid regions protecting from biotic interference.

• They increase above and below ground ecosystem biodiversity and help in improving global climate change by sequestering carbon in their biomass as well as in the soil.

Agro-Forestry Systems and Soil Fertility

In agroforestry systems, nutrient absorbed by the roots from deeper soil layer add in upper surface of soil through leaf litter. Tree roots harbour many beneficial organisms and enhance microbial activity in the rhizosphere of roots. Nutrient cycling is another means in which trees draw large portion of absorbed nutrients from deeper soil layer in returned to the soil through crown wash, stem flow and leaf fall. The accumulated litter after decomposition releases nutrients for reuse by tree stand. In organic matter addition to soil, tree roots play vital role and about 25% of total living biomass of the trees. Quick growing nitrogen fixing trees when combined with herbaceous crops enhance fertility status of soil through litter contribution and nitrogen fixation.

Agro-Forestry Systems and Soil and Water Conservation

Himalayan regions are characterized by marginality, inaccessibility, high intensity rain fall, steep slopes, large scale deforestation and faulty management practices. Natural resources face great stress due to mounting human and livestock pressure. The frequent natural disasters like landslides, floods, droughts and deterioration of water bodies due to enhanced deforestation, conversion of marginal land or forest land into agriculture and unscientific developmental activities further aggravate the problem. Soil erosion is the major bottleneck in cultivation. High intensity precipitation in the rainy season causes excessive run off and soil loss. Due to loss top soil, the crop yields in the region are low as well as variable. Therefore, prominent agroforestry interventions have played important role in conserving soil and water and arresting environmental degradation in the region. Alley cropping and vegetative barriers with *Leucaena leucocephala*, *Vetiveria zizanioides*, Guinea grass and *Panicum maximum* are well accepted by the people for reducing soil and water loss.

Agro-Forestry Systems for Food and Nutritional Security

Home Garden

This is an ancient type of farming in which coconut, arecanut, guava, mango, citrus, tamarind, jackfruit, papaya, banana, moringa, sesbania, custard apple and many multipurpose trees are grown. They used to provide fruits, vegetables and spices. Among vegetables, arrowrrot, cassava, dioscorea, sweet potato, taro, elephant yam are common. Cardamom, cinnamon, clove, ginger, nutmeg, pepper and turmeric are among expensive spices. Pineapple, guava, jackfruit, mango, papaya and citrus are common backyard fruit trees. *Ceiba pentandra* (Kapok) is common tree planted along the boundary to provide fibre from its fruits. Cattle and poultry manure are the main organic sources for homesteads. Forage grasses like stylo, napier, guinea grass and broom grasses are also grown frequently. Mangroves form an essential part of homesteads of back water areas in low lands. Coconut and pandanus are commonly seen near canals and back waters. Palymyrah palm (*Borassus flabellifer*) is the common multipurpose palm found in drier parts of the country. It produces fruits and thatching materials. Fish and shrimp culture in backwater channels and in association with mangroves is another activity observed in homesteads.

Agri-Horticulture

This system can provide sound farm economy, improved nutrition and health standards for the family and stability of income. In arid regions, fruit crops like ber, pomegranate and aonla and intercrops like moong bean, mothbean and cluster bean are grown every year. In semiarid locations, mango, sapota, guava, tamarind, cashew nut, jackfruit, phalsa, wood apple, passion fruit are suitable alternatives for the systems. For hilly regions, fruit crops such as citrus, peach, plum, pineapple and intercrops like ginger, turmeric, french beans, cucurbits, radish etc are grown every year.

Silvipasture

Silvi-pasture woody perennials provide a fodder protein bank. Trees and bushes supply green fodder in rainy season when grasses are not available. These systems are most suitable for degraded lands and for areas facing acute shortage of fodder. Suitable species for silvi-pastoral systems are given below:

(a) Trees, shrubs, grasses and legumes for salt affected areas:

Trees and shrubs: *Leucaena leucocephala, Acacia nilotica, Dendrocalamus strictus, Dalbergia sissoo, Albizzia lebbek, Prosopis julifera, Terminalia arjuna, Azadirachta indica*.

Grasses and legumes: *Chrysopogon fulvus, Cenchrus ciliaris, Pennisetum pedicellatum, Saccharum spontaneum, Dicanthium annulatum, Phaseolus atropurpureus, Stylosanthes* spp.

(b) Trees, grasses and legumes for semi-arid regions:

Trees: *Acacia* sp., *Ailthes excelsa, Albizia* sp., *Azadirachta indica, Dalbergia sissoo, Leucaena leucocephala, Prosopis julifera, Zizyphus mauritiana*.

Grasses: *Chrysopogon fulvus, Cenchrus ciliaris, Pennisetum pedicellatum, Panicum maximum*.

Legumes: *Stylosanthes hamata, Stylosanthes scabra, Clitorea ternatea*.

(c) Trees, grasses and legumes for arid regions:

Trees: *Prosopis julifer, Prosopis cineraria, Acacia tortilis, Acacia raddiana, Acacia senegal, Zizyphus mauritiana*.

Grasses: *Panicum turgidum, Panicum antidotale*

(d) Trees, grasses and legumes for hill regions:

Trees: *Gmelina arborea, Morus laevigata, Gliricidia maculata, Pinus kesiya, Alnus nepalensis, Erythrina indica, Moringa oleifera*

Grasses: *Thysolema maxima, Napier grass, Stylosanthes* spp.

Legumes*: Phaseolus vulgaris, Vicia faba, Vigna* spp.

Agri-Silvi Culture

The intercropping of annual food crops and woody perennials in a land use systems enhances productivity and ensure sustainability. At the same time, it helps to stabilize slopes, minimize erosion and fulfill the farm needs for fuel wood, poles, small timber, fruits and nuts or organic manure and fodder.

Agro-Forestry Systems for Human Health and Climate Change

Human Health

Herbal medicines play an important role in alleviating diseases and disorders in tribal and rural areas. In Africa, *Prunus domestica* has been domesticated the bark of which is highly valued for prostrate disorders. Another multipurpose tree, *Warburgia ugandensis* found in the low land rainforest and upland dry evergreen forest of Africa, the bark, root and leaves of which are valued for treatment of malaria.

In India, cultivation of medicinal plants like neem (*Azadirachta indica*), aonla (*Emblica officinalis*), Hara (*Terminalia chebula*), Bahera (*T. belerica*), Bel (*Aegle marmelos*), Mahua (*Madhuca latifolia*), Mentha, Aloe, Tulsi, garlic, imli, sanai, *Terminalia arjuna etc*. in different agroforestry models have made tremendous effect in improving health and economic viability of rural people.

Climate Change

Agroforestry has dual advantages storing carbon through enhancing build up of soil organic matter and by adding leaf and root biomass that would pool more carbon dioxide out of the air. Poplar shows some of the highest carbon dioxide exchange rates and photosynthetic capacities among woody plants. This tree forms a unique combination with agricultural crops for carbon sequestration in the atmosphere. Similarly, usage oils of *Jatropha curcas* as biofuel help in mitigating the effect of global warming.

Agro-Forestry and Biodiversity Conservation

In India, it is estimated that biological diversity has more than 45,000 plant species and 81,000 animal species covering about 7% of the world flora and 6.5% of world fauna. Agroforestry interventions contribute to biodiversity conservation through integrated conservation development approach. It helps in improvement in new varieties and population. In north east India, polyculture of indigenous trees and crops form a multi strata system like a natural forest.

Plant Diversity in Traditional Agroforestry Systems in NE Region of India

Staple food crops: *Oryza sativa*, *Zea mays, Eleusine coracana*, *Ricinus communis*.

Vegetable crops: *Solanum melongena, Capsicum* sp., *Lycopersicon esculentum, Brassica oleracea var. capitata, Brassica oleracea var. botrytis, Brassica campestris, Brassica nigra, Cucurbita moschata, Momordica charantia, Luffa cylindrica*.

Root and tuber crops: *Colocasia* sp., *Dioscorea* sp., *Ipomeae batatas, Manihot esculenta, Zingiber officinale, Curcuma longa, Solanum tuberosum, Allium satuva, Allium cepa, Raphanus sativus, Daucus carota*.

Fruit and nut crops: *Carica papaya, artocarpus heterophyllus, Mangifera indica, Ananas comosus, Citrus* sp., *Musa* spp., *Zizyphus jujubae, Dillenia indica, Psidium guajava, Pyrus malus, Pyrus communis, Prunus domestica, Vitis vinifera, Areca catechu, Cocos nucifera*.

Timber yielding crops*: Duabanga* sp., *Terminalia myriocarpa, Michelia champaca, Gmelina arborea, Anthocephalus cadamba, Pinus wallichiana, Morus laevigata*.

Bamboos: *Bambusa tulda, Bambusa nutans, Bambusa pallida, Bambusa balcoa, Phyllostachys bambusoides*.

Canes/ Ratan: *Calamus, leptospadix, C. tenuis, C. erectus, C. floribundus, C. inermis, C. gracilis, Plectomia himalayana, Zalacca sacunda*.

Weeds: *Bidens* sp., *Eupatorium odoratum, Lantana camara, Ageratum conyzoides, Boer haavia hispida, Spilanthes* sp., *Sida aquata, Michenia* sp., *Mimosa pudica, Leucas aspera*.

Grasses: *Setaria glauca, Cynodon dactylon, Panicum* sp., *Thysanolaena maxima, Tridex* spp.

Agroforestry Systems and Shifting Cultivation

Shifting cultivation is practiced in 2.4 mha in many parts of India. The prevalence of shifting cultivation with short cycle, raised bed along the slopes and pervasive deforestation has led to degradation of soil, water, flora and fauna in these areas. Agroforestry has a long tradition plays an important role to improve livelihood security through higher income and creating more employment in addition to reduce the

soil erosion and deforestation.

Eco-Agriculture

This ensures healthy farming and healthy food. It protects the soil, the water and the climate. Ecological farming rejects genetically modified crops, chemical fertilizers and pesticides. Eco-farmers limit insect damage to their crops by avoiding large monocrop plantation and preserving ecosystem diversity. It restores soil nutrients with natural composting systems. These types of farming take advantages of natural ecosystem services, such as water filtration, pollination, oxygen production and disease and pest control.

Permaculture

This is an approach to land management and settlement design that adopts arrangements observed in flourishing natural ecosystems. It is an agricultural system or method that seeks to integrate human activity with natural surroundings so as to create highly efficient self-sustaining ecosystems. Examples include buildings that support outside plant life, backyard and balcony gardens and energy saving green initiatives such as the installation of gray water reclamation systems. Three ethical principles of permaculture are *Care of Earth*, *Care of People* and *Return of Surplus to Earth and People*.

Conclusion

The nutrient management, pest and disease management practices to sustain the yield levels during conversion period and standardization of package of practices for organic production. Small holdings and diversified farming situations need greater on-farm and farmers' participatory technology development to get sustained gain in production. As profitability, environment and social relations need to be continually monitored to improve the system, creating a more sustainable agriculture require a closer relationship between agricultural research and producers.

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