Integrated Farming System
concept & farm design

DRCSC

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1.0 Story from the past

The newly developed concept of integrated or ecological farming is a synthesis of our age-old traditional knowledge and modern scientific techniques.

Early in our civilization the source of food was mainly through collection or hunting. That was the age of the hunter-gatherers. As people started to settle down as communities in villages, they felt the need for a more stable food and perhaps fodder production system. What was the inspiration for our ancestors? The natural production system of course —, those pastures, those forests. After all, what can be more productive than a lofty forest? Talking about sustainability can any production system be more sustainable than a forest? Quite naturally our early agriculturists emulated the natural production systems as they started the business of growing food instead of hunting and gathering.

Such agriculture-system had the diversity alike any natural system. Such a set up was self contained and self sufficient, i.e. it did not require any input from outside the farm or village. The farmland of a farmer gave him or her at least enough to feed the family. Slowly through the ages, our agriculturists developed a rich body of knowledge about how to produce while in tune with nature and without harming the nature. Such a farm was more cushioned against natural or climatic risks too.

The farming system that developed in our own country also evolved along the similar line. It evolved keeping in tune with the local ecological phenomena and the resources that were available locally. Considering the rich diversity of agro-ecological settings, a rich variety of farming methods evolved across the length and breadth of our country- each with its own features and each with its own body of agro-ecological knowledge systems.

"But Traditional Technologies did not Produce Enough"

Way back to sixties, country was going through severe food crisis. As we could no longer expand our arable lands much, the challenge was to increase the productivity of our farmlands to feed the fast growing population. The traditional agriculture were failing us we were told. We needed to "Modernize" it and we needed new technologies – we were told. Although it remains a matter of debate as to, whether the food shortage was due to 'low productivity' or had to do with almost non existent 'public distribution system', country's agricultural establishment decided that the low external input traditional agriculture was the reason

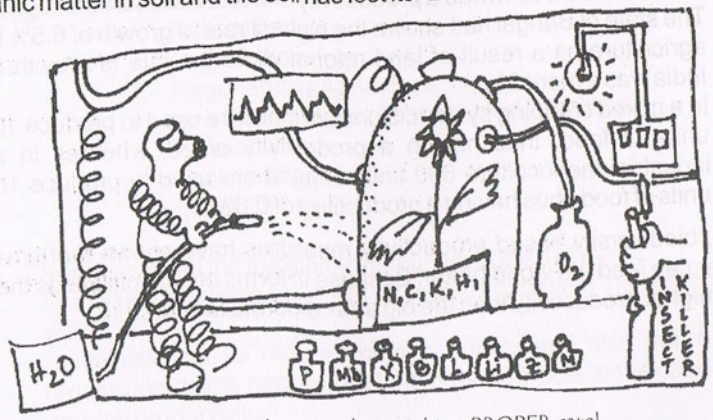
for low yield. All of a sudden it appeared to be 'non scientific' — 'primitive' and had to be done away with. Instead, a 'more scientific' and 'modern' high external input based agricultural system was pushed ahead to solve the problem. The era of Green Revolution began. Green revolution did hike up the productivity of our agricultural lands many fold. Country's food stores swelled over the next few decades. Whether that increased food production reached each of our starved and half starved countrymen is another issue — but the fact is that, our food grain production has indeed improved.

But, what happened to the Green Revolution that was thought to be the answer to the food insecurities of our growing population? There are again serious crises in our food production today. A whole range of problems suddenly plague our agriculture. Productivities are falling. Farmers are committing suicide. Hundreds of small and marginal farmers are migrating to the urban centers in search of job. Yet country's population continues to grow as before. There are serious concerns all over again today whether we shall be able feed our teeming millions in a decade from now?

What has gone wrong?

1.1 The Fading Green!

Seems the new and "Modern" technologies are failing us too.
Rampant use of chemical fertilizers has led to the steady decline of organic matter in soil and the soil has lost its "Life".



The modern day agriculture, taking PROPER care!

Thanks to the indiscriminate and erratic use of chemical pesticides — our natural ecosystems are poisoned — the food that we eat is poisoned and everyday there is a newer variety of pest in our crop fields that has grown resistance to pesticides.

Our groundwater store is declining fast. Thanks to the green revolution that prompted our farmers to tap this aquifer for doing agriculture. The heavy mining of groundwater has led to arsenic contamination.

Our rich crop diversity is as good as lost. Thanks to the handful of 'High Yielding' and 'Improved' crop varieties that now sway in our farmlands.

The small and marginal farmers today are at their wits end. Market dictates them today about what to grow and when not to eat, what they grow but sell it in the market to get some cash in hand to buy food from the market!!!

1.2 The Myth of the unproductive small farmers...

The main argument used for the industrialization of food and corporatisation of agriculture is the low productivity of the small farmers. Some statistics (World Development Report and Report of International Conference on Globalisation, Food security and Sustainable Agriculture, New Delhi 1996) to prove the 'fallacy' of the myth:

- In Brazil, the productivity of a 0-10 ha farm was worth $85 / ha while the productivity of a 500 ha farm was worth $2 / ha
- In India a 0-5 acre farm had a productivity of worth Rs 735/acre, while a 35 acre farm had a productivity of worth Rs. 346/acre.
- The state of Bengal had shown the highest rate of growth of 6.5% for agriculture as a result of land reform, while the rate of growth for India was a mere 3%.
- In a mixed cropping system, 5 units of input are used to produce 100 units of food, thus having a productivity of 20; whereas in an industrial monoculture 300 units of input are used to produce 100 units of food, thus having a productivity of 0.33.

Thus, biodiversity based productivity measures have shown that small farmer can feed the world better. Because in terms of multiple yields they have higher productivity than the big and corporate farmers.

2.0 What we are trying to do

Solution to the whole range of problems that has surfaced after three and a half decades of green revolution is not an easy one. There is simply no short cut.

Several solutions have been suggested in the recent past.

Most of these have one thing in common. Most of these, centred on the organic path. Most agreed that the new path should be a sustainable one. Call for a sustainable solution found voice in the declaration that came out of the 1992 Earth Summit at Rio de Janeiro too.

Sustainable solutions have been proposed by –

- The proponents of the organic farming movement
- The state agriculture establishment
- and even by the multinational corporates

Suggested solutions exist in the name of –

- Natural Farming
- Organic Farming
- Regenerative Agriculture
- Low External Input Sustainable Agriculture
- Permaculture
- Ecological Agriculture
- Integrated Agriculture

- Some said that the traditional agriculture is the answer.
- Some said that replacement of inorganic inputs with the organic ones will do.
- Some said, let us reduce chemical inputs and also put in some organic inputs too because just the organic inputs alone cannot give enough productivity.

- and there are some, who suggested structural and functional integration of farming components as road to sustainability.

We felt that each of this recommendation offers partial solution. Although most of the suggestions are honest ones, there are also such suggestions that either has profit making motif or are still dismissive about the failure of high external input agricultural philosophy. We also felt that the answer is around the last of the list, which refers integration at structural and functional level.

We felt that the answer lies in (according to order) —

- Probing deeper into the rich knowledge base of our heritage of low external input agricultural systems and understanding the natural productive ecosystems.
- Learning more about the various Biological resources in and around the farm-
  - what are their respective potentials.
  - how can they be so integrated that together they improve the productivity of the whole farm.
  - how can the various components of a farm be so integrated that there is total or near total functional complementarities.
- Fine tuning and building upon such a knowledge base to evolve a farming system that is based upon the guiding principles of natural productive ecosystems and our heritage farming knowledge system.
- Total ban on application of toxic chemicals or even doubtful and untried organic amendments like Biotechnological Agro-inputs or Genetically Modified Components in the farm.
- Trying to form like - minded farmer groups, next to each other if possible, who would practise similar farming as a group.
- Last but not the least, trying to improve the surrounding biological resource base or in other words the surrounding ecosystems.

We believe that these will achieve the following:

- It will increase the opportunity of work along with availability of food, fodder and fuel in the village.
- It will save and conserve environment and natural resources from being destroyed.
- It will enhance the global relationship after maintaining the originality of socio-cultural characteristics of each areas.

Bio-integrated farming is one possible way to achieve this.

We are actually trying to find out some alternatives to these problems through some resource management. This aims at increasing crop diversity, productivity and sustainability. This would also enable the farmers to think scientifically, make them self sufficient regarding production and supply of seeds, fertilizers, pesticides. It will also make them aware about importance of farming in tune with the nature and its laws.

Most of the farmers in our country possess less than an acre of land inclusive of paddy field, pond and homestead. Neither do they have more than rupees 4000-5000 per bigha to invest (some farmers have to borrow even this amount!), nor can they earn any significant amount of profit even after cultivating paddy almost thrice a year (that too, if there is no drought or flood). Most of these farmers possess one/two goats, 10-12 ducks or hens, one/two cattle (which are substituted by pigs in many dry areas or areas dominated by tribal communities).

Let us try to understand this with an **example**.

Take an **alluvial floodplain or river basin** as the setting :

- In such region soil is clayey.
- Almost each farming family has a pond of area 2-3 decimal.
- The small farmers usually don't have plough of there own, so they have to hire tractors and power tillers and also have to pay for the water used for irrigation.
- There are many fruit trees and multipurpose trees like Coconut, Jackfruit, Guava, Papaya, Banana and so on are very common around the houses ranging from 4-5 to 10-12 in number.

Let us try to design a farming system model for these farmers.

Before designing, let us try to define aim and techniques of integrate farming again.

1. The diversity of the farm should be increased as much as possible by introducing at least 5/6 types of **cereals and pulses/oilseeds**, 10-12 varieties of **vegetables**, 5-6 varieties of **fruit trees, fuel wood** and fodder trees, 5-6 types of **spices** or **medicinal plants**, 5-6 types of **livestock**, 3-4 types of **fish**. That could ensure food and livelihood security throughout a year.
2. External inputs will have to be reduced. At least 1-2 members of each family should take the responsibility to produce inputs like seeds, fertilizers etc. and to cover the field with live fence from within

the villages.

3. Measures should be taken to conserve soil and to harness rainwater. Measures should be to prevent water run off and soil erosion.
4. The organic wastes generated from farms, cowshed, household should be reused, best would be to recycle them. For example excreta of livestock can be used to produce biogas, a part of the liquid slurry obtained as a byproduct of the process, can be used as fish feed and rest can be applied to paddy or vegetable field.
5. Even the inherent behaviour of the livestock can be utilized also. If the integration is done at right time and quantum, they might serve many of our purpose free of cost. As hens can provide fertilizers in fruit orchard along with clearing up weeds and pests; local variety of ducks and predator fishes kept in paddy field can save works like weeding, fertilizing, aerating and so on.
6. Water hyacinth and other organic weeds like Cassia tora, Ivy Gourd, Prickly Amaranth, Lambs quarters (Chenopodium album) etc., which are grown on its own, should be processed and utilized to meet consumption requirements of human and livestock.
7. Fast growing trees like Gliricidia, Ipil Ipil, Common Sesban, Variegated Bauhinia (Bauhinia variegata), Pigeon Pea, Bamboo should be planted as they add high nutrient content in soil. They can be used for enriching soil as well as fodder of livestock. At the Same time these may also be used as firewood.
8. Farmers should take initiative to sell their products, not directly from field, but should process them, which help them to earn more profit. And this is also a good process to keep the organic wastes within the village. Selling of mango leather instead of mango, extraction of oil from Neem/Indian Beech (Pongam Oil Tree)/Castor within the village, selling of fruit juices are few examples of such post harvesting technologies.
9. Uses of chemical pesticides are to be stopped while practising integrated farming. In fact, use of chemical fertilizers like Urea, Super Phosphate, Ammonium Nitrate, Potash should also be stopped gradually. Though little amount of chemicals like DAP or NPK can be used mixed with organic fertilizers, yet it is advised to reduce the application. Instead of rock phosphate, limestone, wood ash etc. can be used if required. Emphasis should be given on preparing and using of organic fertilizer, green manure, vermicompost, extract of various plants and weeds or ash as organic weedicide etc.

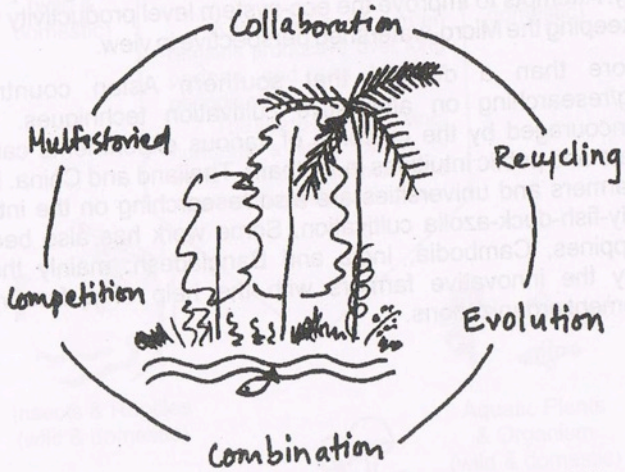
Besides making the farm diversified, there are scopes to create different system level diversity also. If we have different ecosystem like unproductive high land, low lands, productive lands, garden or some wetland together – we can try out different types of farming system and techniques.

2.1 The Model for a Floodplain region farm

The models that would be developed initially at single farm scale are based upon the first principle of ecology that all the components of nature, biotic and abiotic are interrelated. It is an established principle in ecology now, that stability of a system is enhanced by higher connectance among different components of a system. A stable system has:

i. Maximum resilience capacity
ii. Optimum productivity with maximum input use efficiency
iii. Higher sustainability

This has been illustrated amply by a number of experimental validations during the last two and a half decades.



The Natural Ecosystem...can we bring these in our model?

Agricultural systems are essentially 'managed' ecosystems. Even though they are much simpler in structure and complexity than a natural ecosystem they are guided by the same natural ecosystem principles too. The concept of agricultural systems as agro-ecosystems provides a

fundamental insight that any farming system should ideally emulate a productive natural ecosystem. A farm developed under this 'natural' framework may be termed as 'BIO-FARM'.

The model to be developed is envisaged at 2 scales:

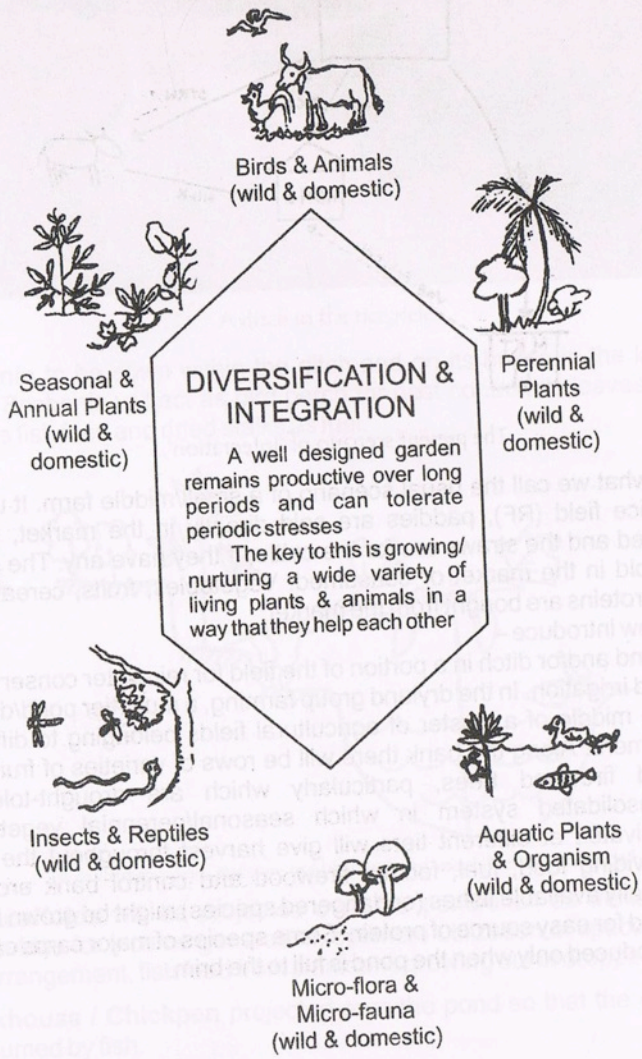
i. Single farm scale
ii. Farm cluster scale

Farm cluster scenario is thought to be an ideal scenario. It is essentially a cluster of BIO-INTENSIVE FARMS. In it, apart from integration at the farm level, there would also be integration of resources that are common to such farms. Ideally such a cluster boundary should be a whole village ecosystem.

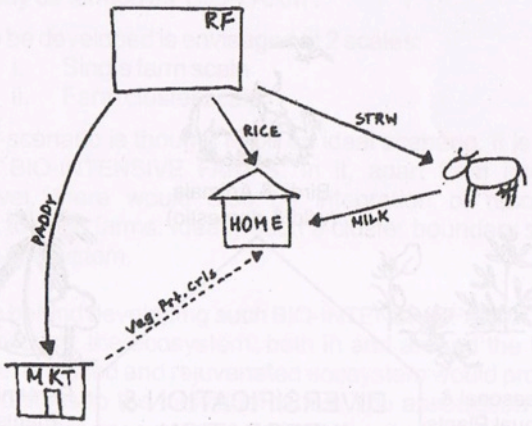
The rationale behind developing such BIO-INTENSIVE FARM CLUSTER is that in this process, the ecosystem, both in and around the farm would ameliorate. An enriched and rejuvenated ecosystem would provide better ecosystem services to the individual farms. The association between a farm and the cluster ecosystem would ameliorate through a process of synergy. Attempts to improve the eco-system level productivity would be made keeping the Micro-watershed perspective in view.

It's more than a decade that southern Asian countries are working/researching on alternative cultivation techniques. Farmers were encouraged by the outcome of various experiments carried out by private and public intuitions in Vietnam, Thailand and China. In Japan some farmers and universities are also researching on the integration of paddy-fish-duck-azolla cultivation. Some work has also been done in Philippines, Cambodia, India and Bangladesh; mainly those are done by the innovative farmers with the help of a few voluntary development organizations.

2.2 The selection of Species: Integrity among diversity



2.3 The Resource Flow – Example of an Ideal Scenario from a sub-humid region of eastern India



The present scenario of 'Integration'...

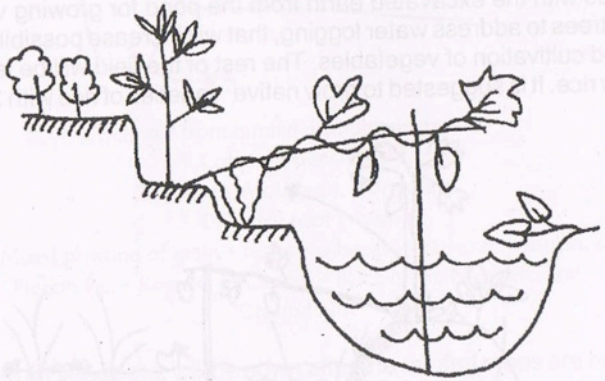
This is what we call the usual scenario of a small/middle farm. It usually has a rice field (RF), paddies are sold directly in the market, rice is consumed and the straws are for the cattle, if they have any. The milk is either sold in the market or consumed. Vegetables, fruits, cereals and animal proteins are bought from the market.

Let us now introduce –

A. Pond and/or ditch in a portion of the field for rainwater conservation and irrigation. In the dryland group farming, a multi-tier pond/ditch in the middle of a cluster of agricultural fields belonging to different farmers. Along the bank there will be rows of varieties of fruit, fuel and firewood trees, particularly which are drought-tolerant, consolidated system in which seasonal/perennial vegetables cultivated at different tiers will give harvest throughout the year providing food, fuel, fodder, firewood and control bank erosion. Locally available fishes (endangered species) might be grown in the pond for easy source of protein. Some species of major carps can be introduced only when the pond is full to the brim.

A ditch in the rice field

Sesbania to be sown within the ditch and on its bunds in the late pre-kharif. Sesbenia will act as bird perch for pest control, its leaves can be used as fish feed and dried stalks as fuel.

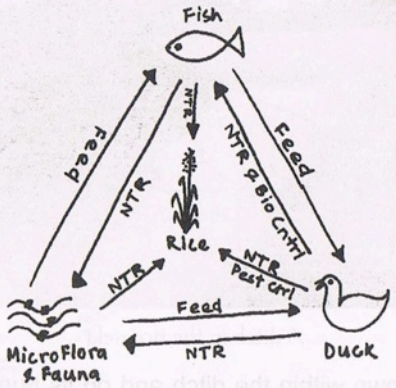


A multistep-pond, steps are used for growing vegetables as water receds

Net/scaffolds will be projected over the pond/ditch as trellis to grow vegetables for income generation, optimum utilization of space by multi-tier arrangement, fish feed from planktons growing out of dropped leaves.

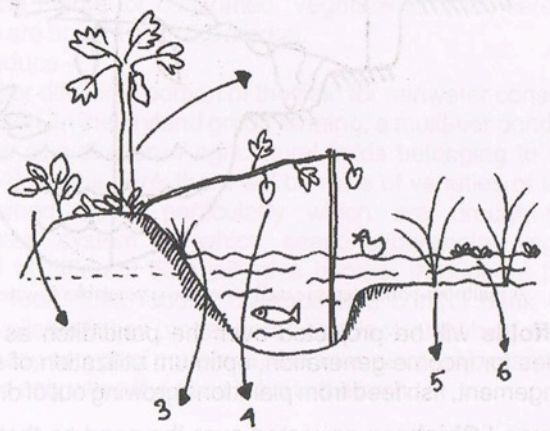
Duckhouse / Chickpen projected over the pond so that the droppings consumed by fish.

B. Fish, duck, azolla in the pond, ditch and rice field for improved nutrition, pest and weed control, aeration, manure and fodder. This is a very good example of intra-subsystem link.



The intra-subsystem in a Fish-Duck-Azolla-Rice system (NTR=Nutrient)

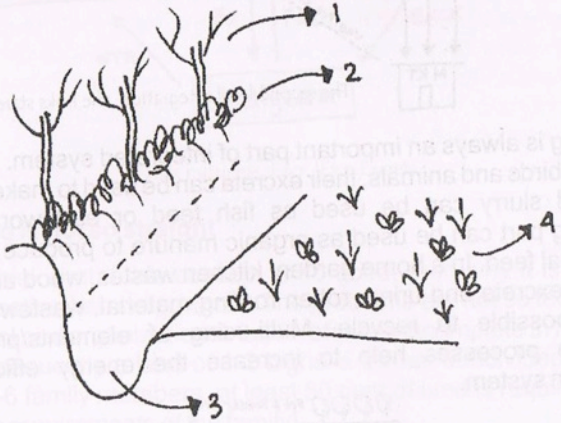
Especially in the wetland, let us raise a portion of the field and widen the bunds with the excavated earth from the pond for growing vegetables and trees to address water logging, that will increase possibility of year-round cultivation of vegetables. The rest of the field will be left intact to grow rice. It is suggested to grow native varieties of rice with 2 saplings



Cross section of a remodeled paddy field for duck-rice-azolla mixed culture

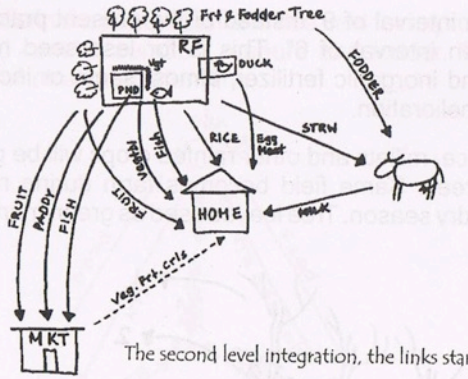
planted at an interval of 9" instead of the present practice of planting 5 saplings at an interval of 6". This is for less seed requirement, pest infestation and inorganic fertilizer, almost same or increased yield and qualitative amelioration.

In dry land, rice, millets and other rainfed crops will be grown in between coppicable trees. Same field becomes farm during rainy season and forest during dry season. Tree leaves used as green manure and fodder.



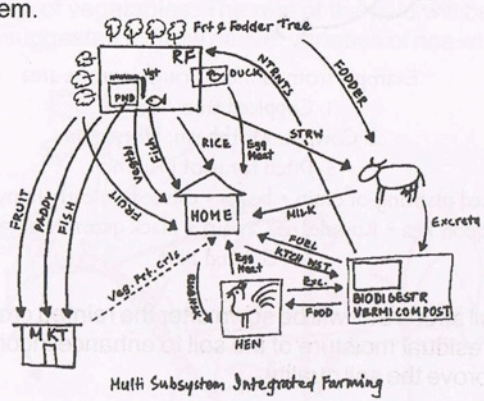
Example from rainfed drought-prone area
1. Coppiced trees/shrubs
2. Cowpea, Mothbean, Horsegram
3. Ditch for root pruning
4. Mixed planting of grain + beans + oilseeds in early rainy season, or Pigeon Pea + Rossele, or Cassava + Black gram, Niger etc. and Ground Nut

Pulses and oil seeds etc. will be sown after the rainfed crops are harvested utilizing the residual moisture of the soil to enhance income and balanced diets and improve the soil quality.



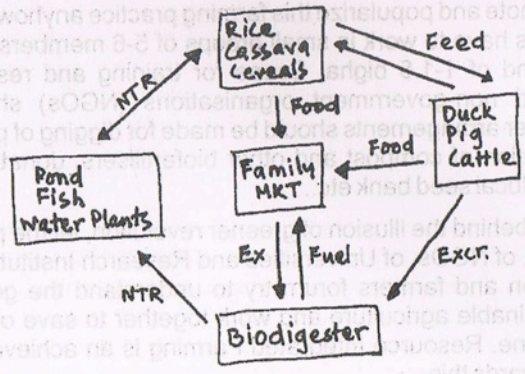
The second level integration, the links stared working...

Recycling is always an important part of integrated system. Plant wastes can feed birds and animals, their excreta can be used to make biogas, and produced slurry can be used as fish feed or earthworm feed and remaining part can be used as organic manure to produce human food and animal feed. In a home garden, kitchen wastes, wood ashes, animal and bird excreta and urine, rotten roofing material, wastewater etc. are always possible to recycle. Multi-using of elements/products and multi-step processes help to increase the energy efficiency of a production system.



The incorporation of a biodigester unit will really make a Multi-subsystem integrated Farming System that we dream.

As a whole, if we generalize the subsystem integration and resource flow, it will be something like —



NTR = nutrients, Excr./Ex = Excreta

3.0 The road is not so straight

We might think that if this concept is so good, then why it is not being followed/practiced at a large scale. The problems are not so technical but mostly social and organizational. Land reform is incomplete in most of the states; consequently a land of 1-2 bigha is further subdivided. But for a farmer of 5-6 family members, at least 50 cent of land is required to fulfill the nutrition requirements of the family!

Distance of the field from the household is another problem, which leads to lack of security. The police, Gram Panchayet (and members of various youth clubs affiliated to different 'isms') has failed to play an effective role in theft of fish/fruit/rice etc..

The location of the land is also a problem. If it is located at one corner along the side of the road or canal, there will be no problem as such regarding widening of the bund and planting trees. But if the land is at the middle of the field, it is difficult to bring such changes.

People who have so far successfully carried out this practice, their land is usually at one corner or side of the field and very near to the homestead. They have also received training or suggestions and short term loans from different organisations. Moreover, all of them are marginal farmers and are very dedicated. We are still skeptical whether this farming practice can be successful if done only to earn profit by employing labour (other than the landowner) in the field.

We need to promote and popularize this farming practice anyhow. For that purpose, farmers have to work in small groups of 5-6 members, each of whom has a land of 1-1.5 bigha. Scope for training and research in government and non-government organisations (NGOs) should be increased. Further arrangements should be made for digging of pond, live fencing, preparation of compost and other biofertilisers, donations and contributions for local seed bank etc..

Without running behind the illusion of greener revolution, let the people of the Government, of NGOs, of Universities and Research Institutes/Labs, farm hands union and farmers forum try to understand the goals and benefits of sustainable agriculture and work together to save our green earth, the only one. Resource Integrated Farming is an achievable and possible path towards this.

Chapter 1: Basic Principles of Farm Design

1.1 Introduction

The past decade has witnessed dramatic changes in the environment in which the farmers operate. There has been an increasing shift into commercial farming as a result of market liberalization policies, the growth of urban population centers, and improvements in transport and market infrastructure. Powerful driving forces are changing farming systems across the world. Urbanization is increasing the number of people for whom food must be produced by farmers, increasingly delivered through supermarkets. As a consequence, farmers are intensifying existing patterns of production, diversifying into new lines, seeking off-farm work, expanding business size and even existing agriculture in an attempt to improve their livelihoods and escape poverty.

Sustainability rests on the principle that we must meet the needs of the present without compromising the ability of future generations to meet their own needs. Therefore, *stewardship of both natural and human resources* is of prime importance. Stewardship of human resources includes consideration of social responsibilities such as working and living conditions of laborers, the needs of rural communities, and consumer health and safety both in the present and the future. Stewardship of land and natural resources involves maintaining or enhancing this vital resource base for the long term.

A systems perspective is essential to understand 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. An emphasis on the system allows a larger and more thorough view of the consequences of farming practices on both human communities and the environment. A systems approach gives us the tools to explore the interconnections between farming and other aspects of our environment.

Farming system is all about coexistence of different species working together to achieve maximum productivity; the process of production should be such that the natural interactions between ecological components are not hampered. In addition to this thrust on productivity, farming also includes within its span, the issues of achieving food,

nutrition and livelihood security, restoring soil fertility, regenerating degraded forests, grasslands and wetlands. Sustainable natural resource management based on bio-organic inputs, ecological design approach, choice of crops and cropping systems appropriate to agro-ecological zones and bio-regions can be one idea to explore with. We also have to empower our small producers through implementation of land reforms, by ensuring access to basic education and health facilities and by creating possibilities of horizontal communication and opportunities of participation in development planning. Well designed agro-ecosystems will conserve soil, recharge ground water, protect habitat for wildlife, enrich culture, provide learning opportunities etc.

Farm management and farming systems approaches help to understand the consequences and opportunities for farm women and men of these changes. An **Integrated Farming System** is about mixing up in proper ratio, the ecological, economical and social understandings with the aim of poverty alleviation through appropriate scientific technology. It approaches to analyze dynamics and diversification and evaluate alternate development pathways for similar groups of farmers. Farm management helps support improved decision making capacity of farmers confronting these rapid changes.

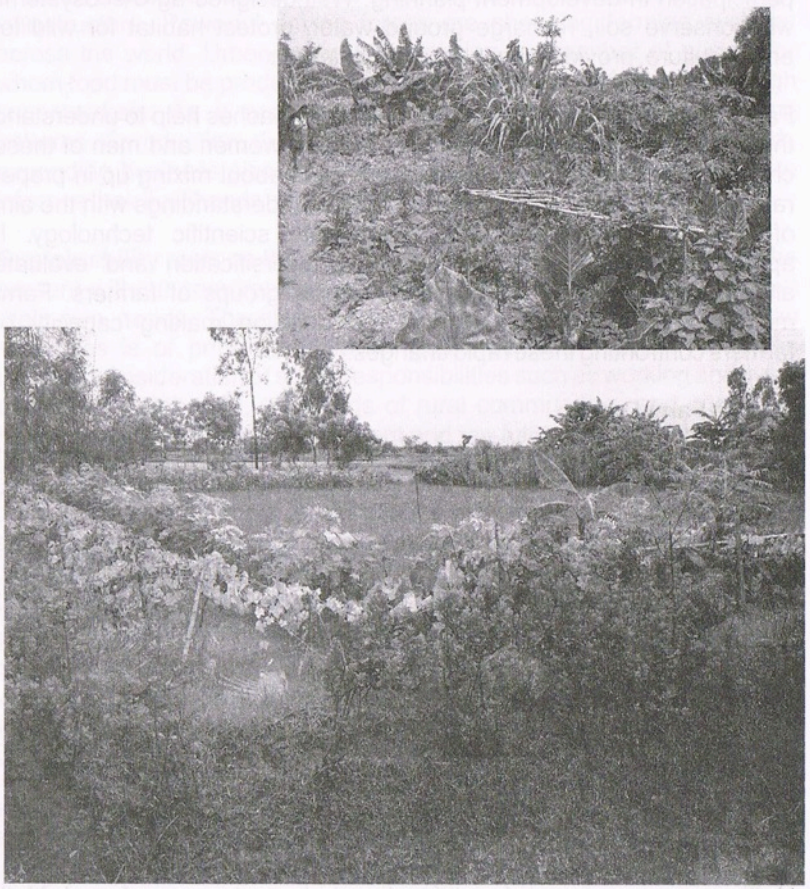
1.2 The Farm Design

The approach to address a farming issue has three aspects, **the input aspect**, the **technical aspect** and **a design aspect**. For instance, if we consider water unavailability is a major issue, the input aspect will be to increase organic matter, so that water holding capacity increases. The technical aspect will be to adopt techniques like mulching, cover crops etc for moisture retention in the soil. The design aspect will be to do land shaping for rain water harvesting and proper utilization of the waste water.

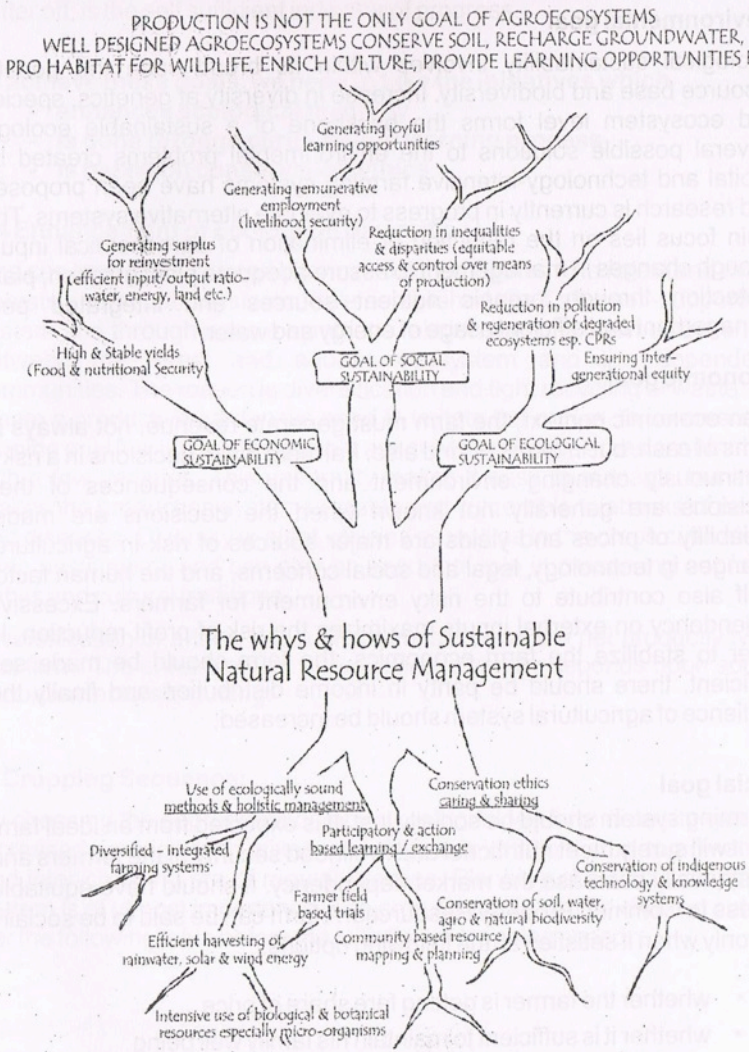
However, in this booklet we will focus on the design aspects.

A design of a farm always depends largely on the agro-climatic condition and constraint and available genetic / human / knowledge / natural resources and the problem facing by the farming community. The Ecological farming, Bio organic farming, Nature Farming etc. all focus primarily on enhancing diversity of genes, species and ecosystem levels. Multipurpose species and multifunctional elements are preferred. Multi

story arrangement, harvest energy and water more efficiently, and keep soil covered for longer period, a critical requirement in tropical agriculture; were evapo-transpirational losses are high and rainfall is poorly distributed. Permaculture guiding principle sums up as **"every element in the design should have more than one purpose and every purpose should be served by more than one element"**



1.3 The Why and How of designing a Sustainable Farm



Sustainable Agriculture integrates three main goals – environmental health, economic efficiency and social - economic equity.

Environmental goal

Ecological sustainability involves within its broad span the genetic resource base and biodiversity. Increase in diversity at genetics, species and ecosystem level forms the backbone of a sustainable ecology. Several possible solutions to the environmental problems created by capital and technology-intensive farming systems have been proposed and research is currently in progress to evaluate alternative systems. The main focus lies on the reduction or elimination of agrochemical inputs through changes in management to assure adequate plant nutrition; plant protection through organic nutrient sources and integrated pest management and efficient usage of energy and water.

Economic goal

In an economic context, the farm must generate revenue, not always in terms of cash, but in terms of kind also. Farmers make decisions in a risky, continuously changing environment and the consequences of their decisions are generally not known when the decisions are made. Variability of prices and yields are major sources of risk in agriculture. Changes in technology, legal and social concerns, and the human factor itself also contribute to the risky environment for farmers. Excessive dependency on external inputs maximizes the risk of profit reduction. In order to stabilize the farm economics, the farm should be made self sufficient, there should be parity in income distribution and finally the resilience of agricultural system should be increased.

Social goal

A farming system should be socially just. It is expected from an ideal farm that it will surely meet nutritional and livelihood security of the farmers and substantially decrease the market dependency. It should have equitable access to Common Property Resources. A farm can be said to be socially just only when it satisfies all the following options.

- whether the farmer is getting fare share of price
- whether it is sufficient to maintain his family well being
- whether he get enough remuneration to purchase his food
- whether the minimum wage requirement is attained

Generating more employment scopes where employment is necessary accounts for the livelihood security of farmers. Whether the poor are better off, is the self sufficient indicator of progress.

To achieve these goals, we need to take the initiatives which

- **enhances ecological diversity**
- **is done through participatory learning process**
- **is based on conservation ethics**

1.4 Enhancement of Ecological Diversity

One can learn about diversity from natural ecosystem like forest and river. Forests and aquatic systems have established itself as a self-supportive system and through ages a symbiotic relationship has been established between the forest and aquatic ecosystem and the dependent communities. The reason is diversification and tight recycling of waste. To create a productive garden we need to imitate the nature. In commercial farming only few types of vegetable are grown and large areas are planted with a few varieties. This uniformity makes it easy to manage, but also makes the production system unstable and vulnerable to attacks of pests and diseases. Diversity in plant species as well as in the crops cultivated, keep pests away, and can play an important role in preserving our food habits and cultural traditions.

Diversification of a farm has a direct impact upon the net productivity of that farm. The enhancement of ecological diversity depends upon some important factors including:

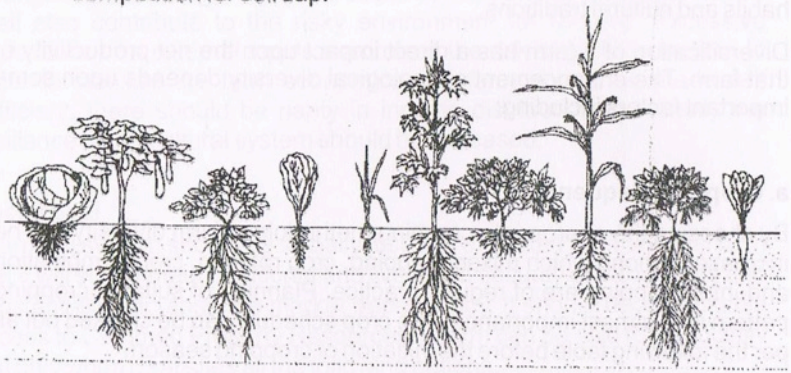
a. Cropping Sequence:

By choosing the appropriate cropping methodology farm diversity can be increased among which mixed cropping, crop rotation, crop combination and inter-cropping are of regular practice. Planning of suitable cropping pattern is of utmost importance. The crop schedule can be chalked out as per the following table before the initiation of cropping season.

Crops	Early Dry Season	Late Dry Season	Early Rainy Season	Late Rainy Season
Leafy Vegetable				
Fruit				
Tuber				
Legume				

The crops need to be selected carefully from the above table. Crop combination is needful to us as the concept paves the way by which there would be:

- Less competition for food: this is achieved by a mixed combination of low feeding crops, medium feeding crops (e.g. herbs) and heavy feeding crops (e.g. cereals, fruits). Soil building plants (legumes) also occupies a major part.
- Space availability for proper root system: The roots of different plants attain different depth. So a proper combination of plants having different root depths help in minimizing the inter-crop competition for soil sap.

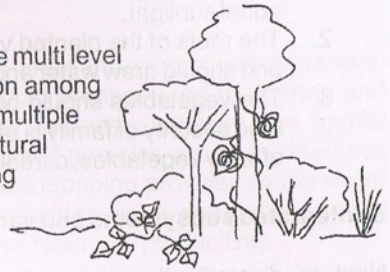


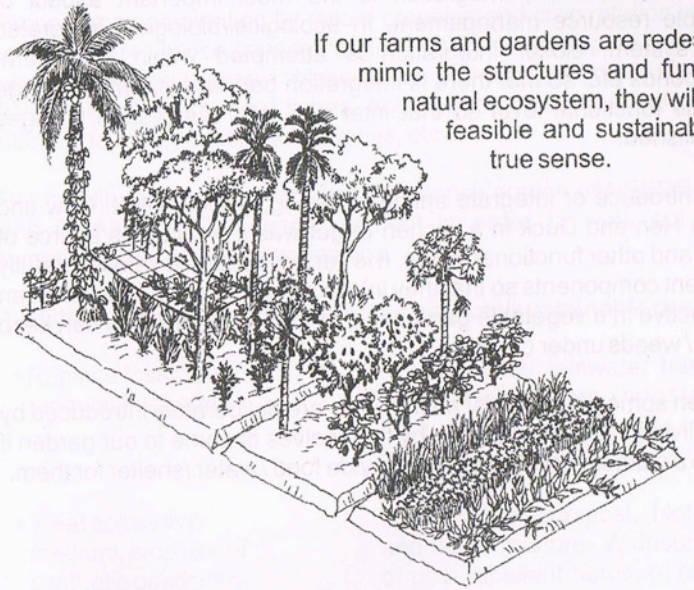
- Duration of crop: It is to note that the chief aim of integrated farming is to minimize the lean period in the field. The intercropping should be done in such a way that the field never remains vacant or unproductive.

Pest control: Companion crops are sometimes helpful in indigenous pest control. Proper selection of some trap crops or pest repellent crops within the mixed cropping can reduce pest attack to considerable level.

b. Multistory Arrangement:

Most natural ecosystems in tropics are multi level arrangements. High level of interaction among biotic and abiotic components and multiple energy exchange routes make a natural ecosystem resilient, self maintaining and highly productive. Moreover, productivity improves over time unlike agro-ecosystems.





If our farms and gardens are redesigned to mimic the structures and functions of natural ecosystem, they will be more feasible and sustainable in the true sense.

During multistoried farming, care should be taken that —

1. The total available area is effectively used.
2. The cultivated crops should get adequate soil sap.
3. The plants should get their required sunlight.
4. The plants should cooperate with each other during growth.
5. Soil fertility should remain intact.

Three rules regarding multistoried farming are :

1. The crops should be planted in an ascending order of their heights from east to west, so that each of them could get equal sunlight.
2. The roots of the planted vegetables should be of different types and should draw water and nutrients from different layers of soil.
3. The vegetables should be identified in such a manner that the food security of family is effectively maintained, i.e., combination of leafy vegetables, cereals, legumes etc.

c. Integrated subsystems and various components :

Next to diversification, integration is the most important aspect of sustainable resource management. In ecological/biological integrated farming system, closer integration is attempted within each farm /garden/ponds etc. so that there is integration both at nutrient exchange as well as functional level so that inter and intra subsystem linkages are established.

We can introduce or integrate animals like Pig, Rabbit, Goat, Cow and Birds like Hen and Duck in a kitchen to get waste product as source of nutrients and other functional inputs. It is very important to select carefully the different components so that they interact positively, e.g. chickens can be destructive in a vegetable garden, but in a fruit orchard they can keep the pests / weeds under control.

In a garden some plants/birds/ animals etc. are deliberately introduced by us; other living things would grow by themselves or come to our garden if we create a suitable environment or provide food / water /shelter for them.

The purposes that are achieved by diversity enhancement are:

1. Spatial utilization
2. Resilience improvement
3. Growing season extension

To utilize all spaces we can attain both direct and indirect consequences. The direct consequence is that it should produce food for human and animals in order to attain nutritional security. Indirectly, the spatial utilization also increases soil nutrients and provides one of the methods for natural soil conservation. Diversified cropping provides all the major six types of food crops along with fodder for human and animals respectively, while the leguminous crops retain soil productivity.

Proper crop combination by mixed cropping and crop rotation also helps to improve resilience capacity against flood, drought, pest-insect attack, etc. — Weeding done by chicken in an orchard, pest control in a paddy field by local ducks, mud fishes, frogs , uses of water logging resistant plants and drought resistant varieties, etc

Permaculture approach recommends consideration of NEEDS, YIELDS and CHARACTER of each element in order to work out mutually beneficial or symbiotic relationships.

1.5 Other important principles of ecological/sustainable design

• Replace fossil fuels renewable energy:	In small trials rainwater harvesting, with check dam construction, manually operated lift irrigation (treadle pump) are being tried out.
• Treat soil as live medium, stop use of synthetic pesticides and biocides:	Use of Vermicompost, biofertilisers and liquid manure. Widespread use of pest repellent herbs, of cow urine as a fungicide, of botanical pest control agents being practised along with mixed cropping/companion planting, crop rotation, seed invigoration etc.

- Look for possibilities hidden within problems: Trials is on to use water hyacinth and other aquatic weeds as mulch and composting material, to use termite as chicken and fish feed etc. Uses of pond bottom silt to improve sandy soil and rice husk ash to amend clayey soil are also examples.

As a whole :

Utilize all space
Improve soil resilience
Extend growing season

↑

to

Enhance Diversity

↑

by

Cropping sequence
Multistory arrangement
Integrating subsystems

1.6 Participatory Learning Process:

PLA or *Participatory Learning Action* and Participatory Rural Appraisal or PRA are two closely related concepts that have become increasingly popular for participatory development. It is an approach for learning and organizing participation of local communities and groups for interacting with them, understanding them and learning from them. These methods enable local people to participate in knowledge building exercises, investigate and analyze their problem, evaluate constraints and opportunities and take informed decisions for perusing goals of sustainable development.

In a PRA/PLA/PAR type approach an "outsider" needs to be aware and clear about the kind of role one is expected to play. The role is that of a facilitator/animator/catalyst supporting and promoting participation. It is the role to be played in offsetting the conventional biases which outsiders generally fall into while conducting field enquiry. They are:

- Roadside Biases (visiting villages well connected by roads)
- Gender Bias (generally interacting with men)
- People's Bias (interacting with key people)
- Time Bias (visiting local people at one's own convenient time rather than theirs')
- Seasonal Bias (visiting local community in dry season and not in problematic season's e.g. rainy season)

The role reversal of an insider is that from "passive" to "active" and creative role, while the outsider's role is that of encouraging and supporting participation, creating enabling conditions and taking lessons leading to community action.

There is perhaps no end to discovery of participatory methods. With each problem, there tends to be an appropriate form of expression, appropriate to explain a particular issue concerned. It also depends on the user who uses a particular method or tool to express himself or herself.

References

1. *Mukherjee, Neela (1997): Participatory Rural Appraisal-Methodology and Application: Concept Publishing Company, New Delhi.*
2. *Mukherjee, Neela (2002): Participatory Learning And Action, with 100 Field Methods: Concept Publishing Company, New Delhi.*
3. *A manual for Participatory Training Methodology in Development (1995): Society for Participatory Research in Asia (PRIA), New Delhi.*
4. *Leurs, Dr. Robert (1993): A resource Manual for Trainers and Practitioners of Paticipatory Rural Appraisal: Development Administration Group, Birmingham, England.*

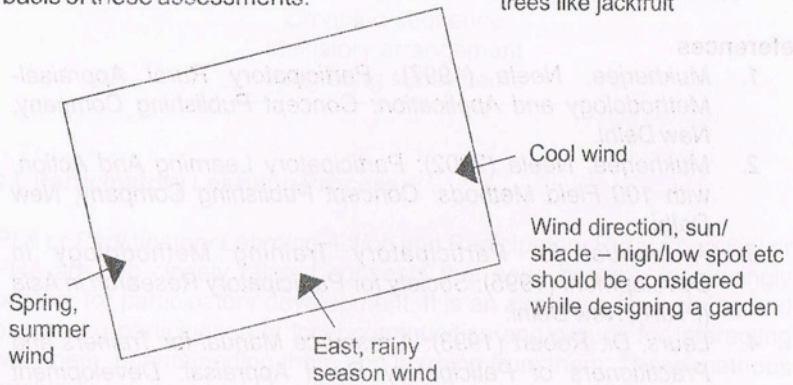
Chapter 2: Designs Suitable for Different Agro-Ecological Region

2.1 Before you start your design

Before you start designing your farm, you need to asses your farm according to following points:

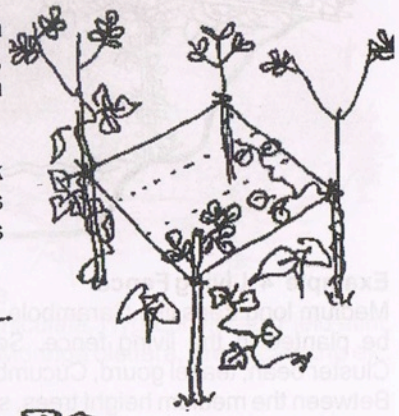
- Existing farm size
- Living area for animal and human
- Ploughing frequency
- Distances of farming areas (field/homestead/orchard/poultry/pond etc) from household
- Weeding style and frequency
- Transport after harvest
- Soil-water conservation techniques
- Existing farm inputs
- Cropping pattern (can use seasonal calendar)
- Type and role of livestock
  - type of shelter
  - type of fodder

Your design will take shape on the basis of these assessments.

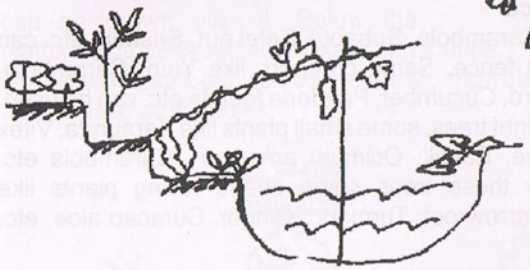


2.2 Design for humid–subhumid region

Example 1 A multi-storey pergola with trees as poles, climbers, creepers, under-storey plants in a home garden.



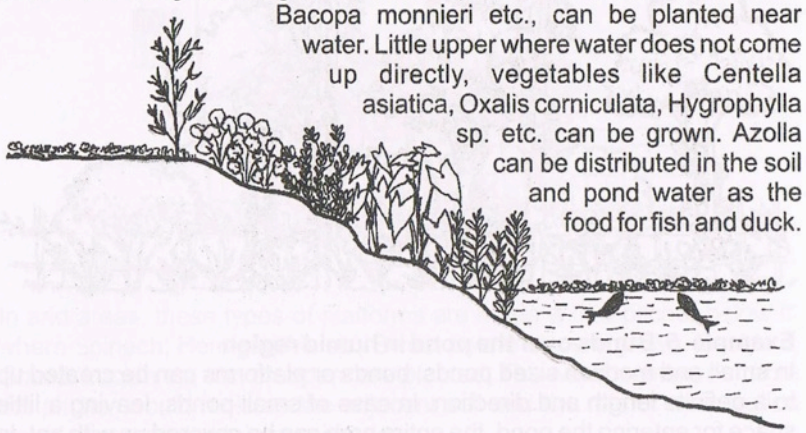
Example 2 A multi-step pond bank in a semi arid area of Bengal. Steps are used for growing vegetables as water recedes.

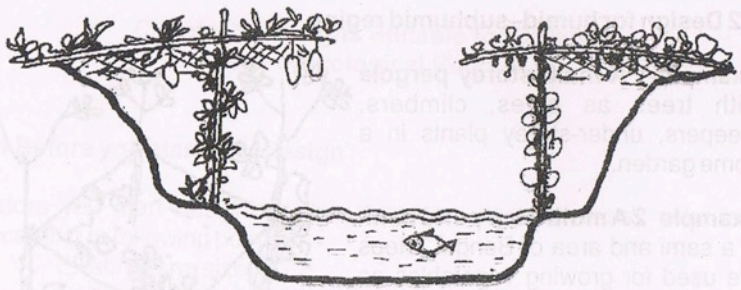


Example 3 Plantation on the bank of the pond

Many plants occur here naturally.

Plants tolerating standing water like elephant ear, Marsilea minuta L, Bacopa monnieri etc., can be planted near water. Little upper where water does not come up directly, vegetables like Centella asiatica, Oxalis corniculata, Hygrophylla sp. etc. can be grown. Azolla can be distributed in the soil and pond water as the food for fish and duck.





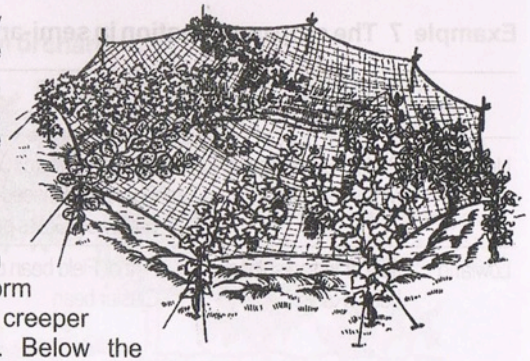
Example 4 Living Fence

Medium long trees like Carambola, Subabul, Betel nut, Sesban, etc. can be planted in the living fence. Some creepers like Yam, Carambola, Cluster bean, teasel gourd, Cucumber, Paederia foetida etc. can be used. Between the medium height trees, some small plants like Karaunda, Vitex negundo, Curry leaf tree, Basak, Ocimum american, Carambola etc. can be planted. Below these trees some shade loving plants like Pineapple, West Indian arrowroot, Turmeric, Ginger, Curacao aloe, etc. can be planted.

Example 5 Bunds over the pond in humid region

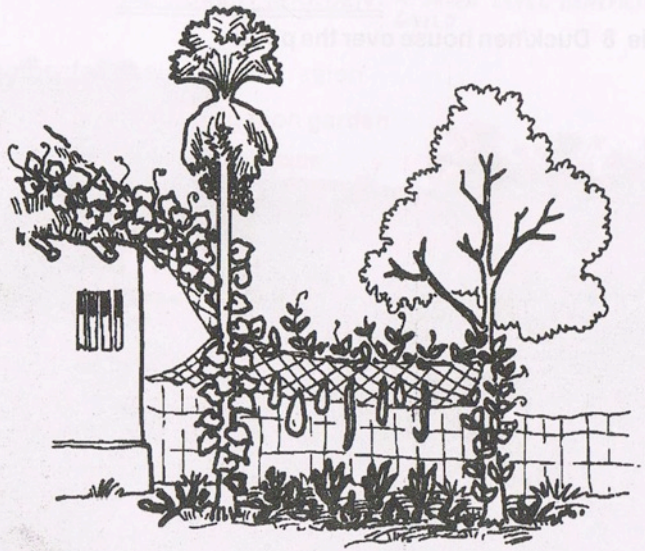
In small and medium sized ponds, bunds or platforms can be created up to a definite length and direction. In case of small ponds, leaving a little space for entering the pond, the entire area can be covered up with net. In

this type of bunds, any creeping vegetables like Gourd, Cucumber, Lucida sp., Bottle gourd, Bitter gourd, etc. can be planted.



Example 6 Scaffold

In any part of the garden or homestead a platform can be made and any creeper can be grown over it. Below the platform, Centella asiatica, Oxalis corniculata, Hygrophylla sp, Field mint, Marsilea minuta L etc. can be grown. Moringa oleifera, Areca catechu etc. can be used as the poles.



In arid areas, these types of platforms are made with a pitcher below it, where Spinach, Hemigraphis sp., Sweet potato etc. are grown. Beside it, Gourd, Lucida sp, etc. creepers are planted. The water coming out from the pitcher would moisten the adjacent soil and the rate of evaporation would decrease due to above shade.

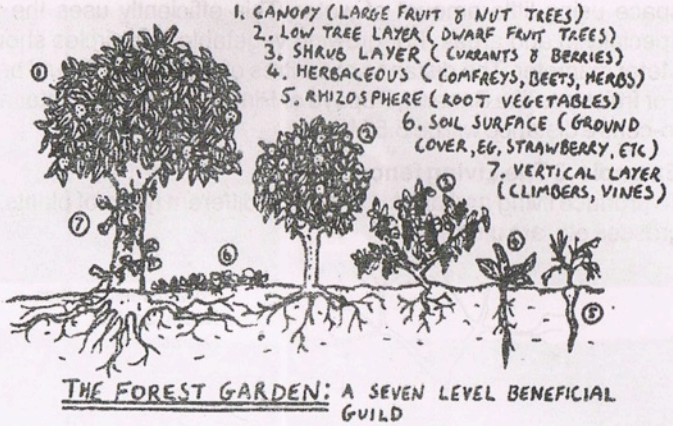
Example 7 The crop combination in semi-arid region

	Rainy/Kharif	Winter/Rabil	Pre-Kharif
Upland	Paddy+Black gram or Maize+Soybean	Wheat+Mustard+Chickpea or Chickpea+Linseed+Sesame or Safflower+Grass pea+Linseed	Cluster bean
Lowland	Jute or Indian spinach. bean+Radish	Pea or Field bean or French Cluster bean	Lady's finger+ or Vegetable Amaranth + Cluster bean

Example 8 Duck/hen house over the pond

The floor of the duck house to be made in such a way that the droppings of the ducks can go directly to the pond and can be used as fish feed. Duckhouse can be replaced by chicken house also.

Example 9 Designing an orchard

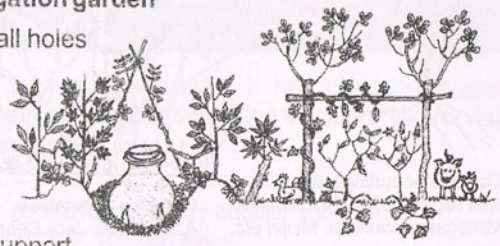


THE FOREST GARDEN: A SEVEN LEVEL BENEFICIAL GUILD

2.3 Suggested design for arid region

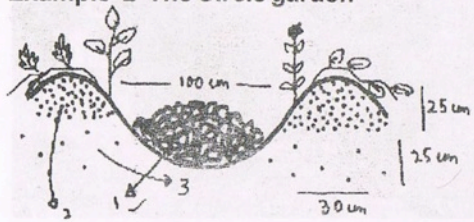
Example 1 The pitcher irrigation garden

A mud pot (pitcher) with small holes at the bottom is installed near a tree or in a center of a bed. For watering the plant/s one needs to put water on to the pitcher which saves almost 70% water! Obviously, it cannot support a large amount of area.



Another important fundamental thing is, cover the soil with any creeper or fodder grass etc., it stops transpo-evaporation loss and generate biomass.

Example 2 The Circle garden

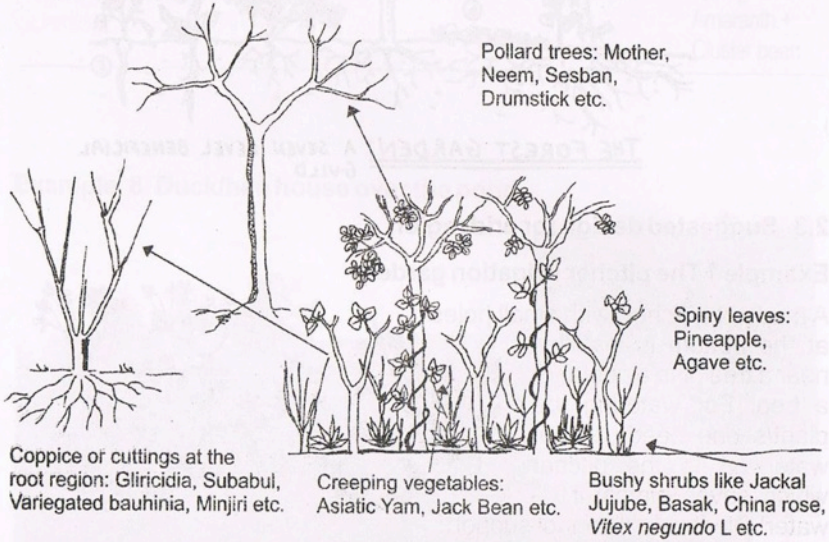


1. Dry and young leaves, kitchen waste, small amount of excreta of hen/duck
2. Mixture compost and dugged up soil
3. Loose soil

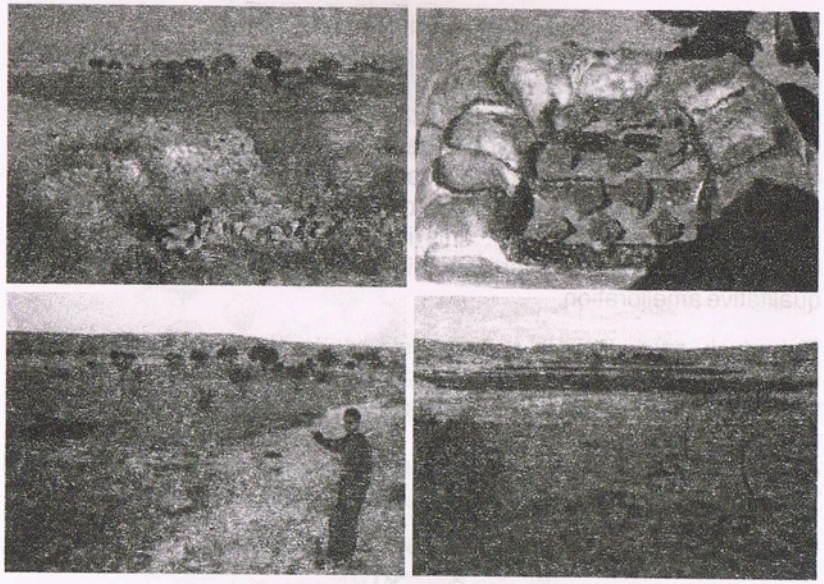
This type of bed is useful for getting different types of vegetables in a small space using little amount of water. This efficiently uses the rain water specially in arid areas. For growing vegetable, the circles should be of 1 Meter diameter. The distance of centres of the circles should be 2 Meters. For fruit trees like Banana, Papaya or Pineapple, the diameter and centre-to-centre distance will be 3.5 Meters.

Example 3 The Living fence

To produce living and productive fence different types of plants, creepers, grasses etc. are utilized.



Example 4 Pasture land development design



These pictures are taken from a desert land. It has used bund and channels to store runoff water from slopes to develop this land. The model described the methods of watershed.

Field bund for soil-water conservation is very popular and used by all of us, are not discussed here. You can see –

1. Integrated watershed management/Rajesh Rajora/Rawat Publication
2. Design and construction of small earth dams/KD Nelson/Inkata Press. Melbourn
3. The myrada experience/Myrada

Example 5 Orchard cum field

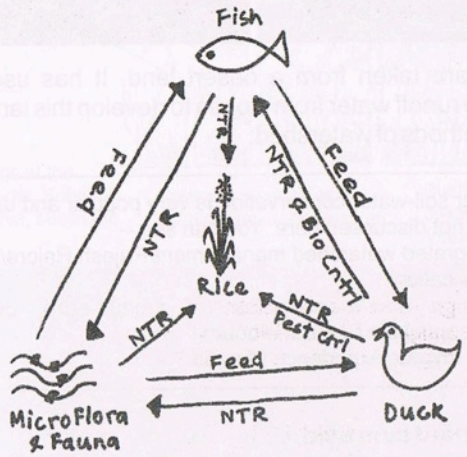
Rice, millets and other rainfed crops will be grown in between copicable trees. Same field becomes farm during rainy season and forest during dry season. Tree leaves used as green manure and fodder. Pulses, oil seeds etc will be sown after the rainfed crops are harvested, utilizing the residual moisture of the soil to enhance income and balanced diets and improve the soil quality.

2.4 Suggested design for water-logged wetland

Example 1 Rice-Fish-Vegetable-Duck-Azolla System

Especially in the wetland, raise a portion of the field and widen the bunds with the excavated earth from the pond for growing vegetables and trees to address water-logging, that will increase possibility of round the year cultivation of vegetable. The rest of the field will be left intact to grow rice. It is suggested to grow native varieties of rice with 2 saplings planted at an interval of 9 "instead of the present practice of planting 5 saplings at an interval of 6". This is for less seed requirement, pest infestation and inorganic fertilizer, almost same or increased yield and qualitative amelioration.

Fish, duck, azolla in ditch and rice field can be introduced for improved nutrition, pest and weed control, aeration, manure and fodder. WE need to select species of fish carefully. The age of the ducklings and rice plant (after plantation) has to be same. For 1ha of land, one can try 20 ducklings. Ducks cannot be allowed after the flowering stage of the rice. This is a very good example of intra-subsystem link.

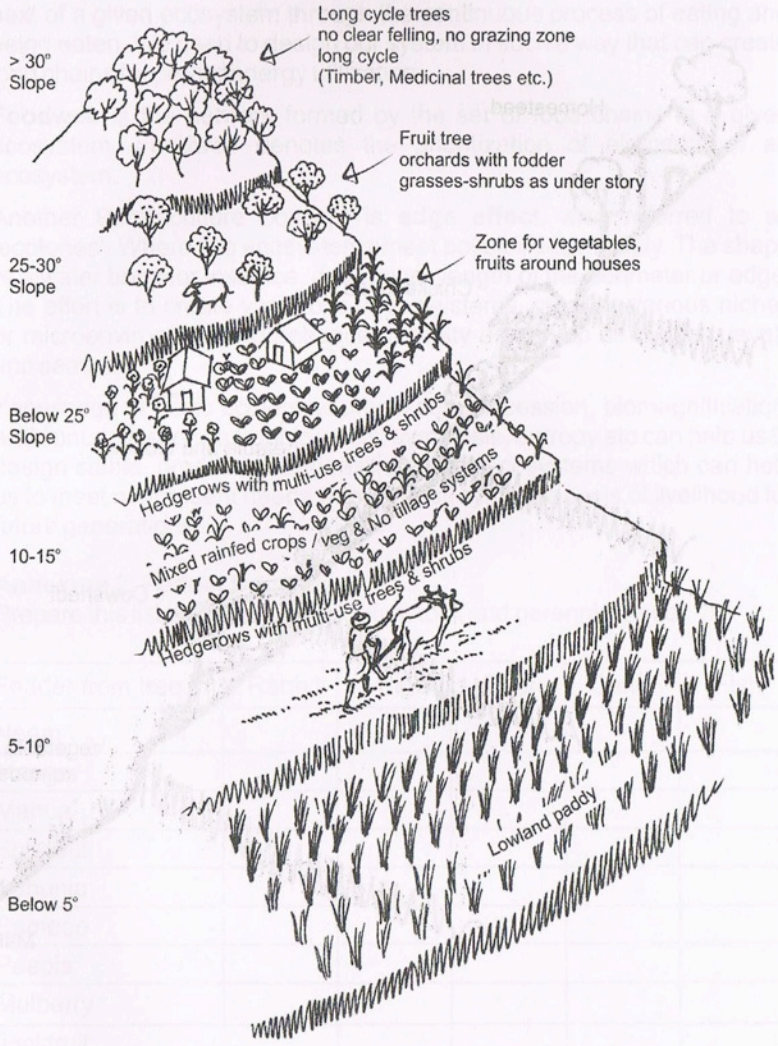


Example 2 Water hyacinth vegetable bed

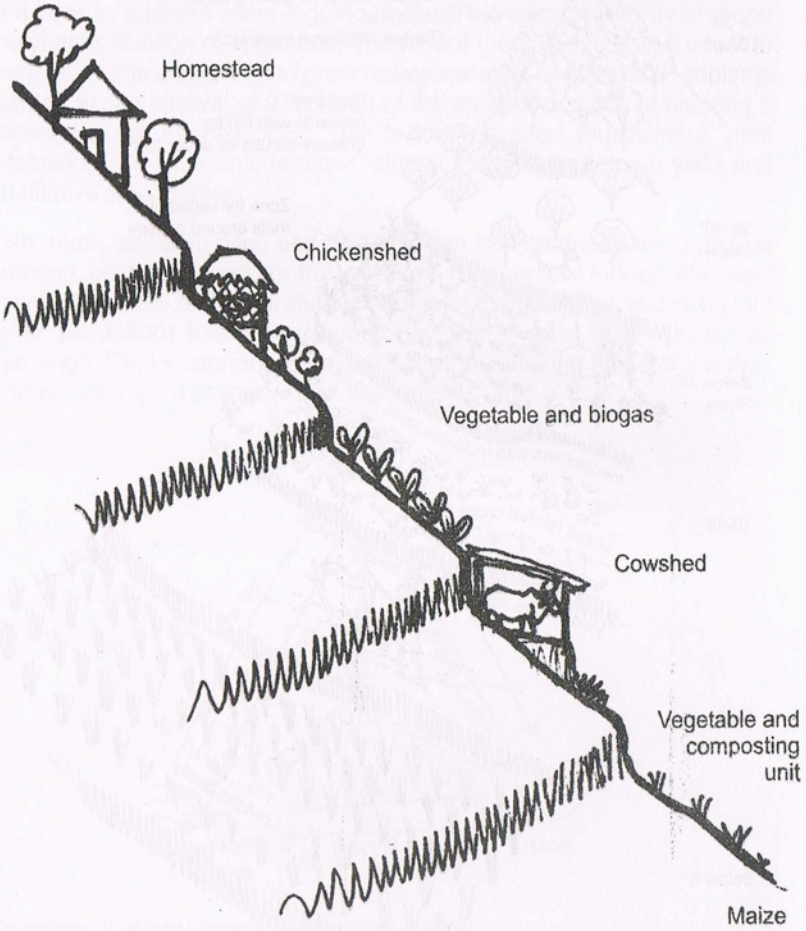
During Kharif, water hyacinth is a dominating waterweed. We can pile up water hyacinth and with a small layer of soil on it, vegetable seedling specially short rooted-short duration vegetables might be raised. Eventually, water hyacinth will be mixed with the soil when water recedes.

2.5 Suggested design for hilly terrain

Example 1 Farm design in a steep slope



Slope >30 degree, can follow the following design for maximum utilization of waste.



Annexure 1: Few fundamental ecological concepts in understanding energy-efficiency in the production system

Foodchain indicates the pattern of energy flow from one tropic level to the next of a given ecosystem through the continuous process of eating and being eaten. We need to design our system in such a way that can create long chains for proper energy utilization.

Foodweb is the network formed by the set of food chains in a given ecosystem. Foodweb denotes the prioritization of elements of an ecosystem.

Another Permaculture concept is **edge effect**, also referred to as 'ecotones'. Where two ecosystems meet possibilities multiply. The shape of a water body for instance, determines length of the perimeter or edge. The effort is to create variations in ecosystems, creating various niches or microenvironments to enhance diversity and fill up all spaces, levels and seasons.

Knowledge of basic ecological processes succession, biomagnification, and concepts such as trophic levels, symbiosis, entropy etc can help us to design stable, productive and resilient agro-ecosystems which can help us to meet our present needs without destroying the basis of livelihood for future generations.

Annexure 2: Fodder from trees

Prepare this list before planning of livestock and perennial trees

Fodder from tree	Rabbit	Pig	Goat	Cattle	Fish
Neem					
Mango					
Mahua					
Subabul					
Bahunia					
Bamboo					
Peeple					
Mulberry					
Jackfruit					

Annexure 3: zone wise tree/crop/herb list

TYPE	SEMI-ARID/SUB-HUMID	HUMID	ARID
Structural Timber	Teak (*Tectona grandis*), Torpedo grass (*Panicum repens* L.), Sisoo (*Dalbergia sisoo*), Melina, Arjun [*Terminalia arjuna* (Roxb.) Wight & Arn.], Rohan, Neem (*Azadiracta indica* A.Juss), Tamarind (*Tamarindus indica* L.), Silver oak, Casuarina, Date palm (*Phoenix dactylifera* L.), Anjan (*Hardwickia binata* Roxb.), Ein, Davana (*Artemisia pallens*), Indian tulip tree (*Thespesia populnea* Soland. ex Correa), Susam, Mango (*Mangifera indica* L.), Acacia [*Acacia nilotica* L. Delile ssp.indica (Benth.) Brenan], Nepal Ebony Persimmon (*Diospyrus tomentosa* Roxb.), Cyamar (*Cymelina arborea*).	Teak (*Tectona grandis*), Sal (*Shorea robusta*), Pine (*Pinus* sp.), *Quercus* sp., Jack fruit (*Artocarpus heterophyllus* Lam.), *Gmelina arborea.*	Rohida, Babool (*Acacia arabica*), Date sugar palm (*Phoenix sylvestris* Roxb.) Neem (*Azadiracta indica* A.Juss), Teak (*Tectona grandis*), *Albizzia* sp.
Multipurpose Trees	Acacia [*Acacia nilotica* L. Delile ssp.indica (Benth.) Brenan], Minar,	Jack fruit (*Artocarpus*	Date sugar palm (*Phoenix*

TYPE	SEMI-ARID/SUB-HUMID	HUMID	ARID
	Cutch tree (*Acacia catechu* Willd.), The flame of the forest (*Butea monosperma*), Bauhinia, Neem (*Azadiracta indica* A.Juss), Indian beech (*Pongamia pinnata* Pierre), Nepal Ebony Persimmon (*Diospyrus tomentosa* Roxb.), Torpedo grass (*Panicum repens* L.), Mahua (*Madhuca indica* J.F.Gmel.), Mulberry (*Moras alba*), Banyan [*Ficus beng(h)alensis* L], Gliricidia [*Gliricidia sepium* (Jacq.) Walp.], *Pithocelium dulche*, Cashew nut (*Anacardium occidentale* L.), Subabul, Coconut (*Cocos nucifera*), Jack Tamarind (*Tamarindus indica* L.), Palmyra, East Indian walnut (*Albizzia* sp.), Arjun [*Terminalia arjuna* (Roxb.) Wight & Arn.], Drumstick (*Moringa oleifera* Lam), Bhumal, Jamun [*Syzygium cuminii* (L.) Skeels], Apricot, Minjiri (*Cassia siamea)*, Raintree (*Samanea saman* Merrill), Cyrewia.	*heterophyllus* Lam.), Mango (*Mangifera indica* L.), Guava (*Psidium guajava* L.), Neem (*Azadiracta indica* A.Juss), Bamboo, Jamun [*Syzygium cuminii* (L.) Skeels], Tamarind (*Tamarindus indica* L.).	*sylvestris* Roxb.), Indian jujube (*Ziziphus mauritiana* Lam.), Kummat, Neem (*Azadiracta indica* A.Juss), Israel Babool, (*Ingadulsis* sp.), Vilayati Babul (*Parkinsonia aculeata L.)*, Date palm (*Phoenix dactylifera* L.), Jangal Jalebi (*Pithecellobium* sp.).

TYPE	SEMI-ARID/SUB-HUMID	HUMID	ARID
Fruit Trees	Custard apple (*Annona squamosa*L), Indian jujube (*Ziziphus mauritiana* Lam.), Kuronda, Mango (*Mangifera indica* L.), Guava (*Psidium guajava* L.), Jamun, Tamarind (*Tamarindus indica* L.), Bullock's heart (*Annona reticulata* L.), Mandarin Orange (*Citrus reticulata* Blanco), Lemon [*Citrus limon* (L.) Burm.f.], Papaya (*Carica papaya* L.), Banana (*Musa paradisiaca* L), Drumstick (*Moringa oleifera* Lam), Sapota (*Achras zapota* L.), Indian Gooseberry (*Emblica officinalis* Gaertn.), Jack fruit (*Artocarpus heterophyllus* Lam.), Aonla, Lichi [*Litchi chinensis*(Gaertn.) Sonn.], Mulberry, Bael (*Aegle marmelos* Correa ex Roxb.), Pomigranate (*Punica granatum* L.), Falsa, Cashew nut (*Anacardium occidentale* L.), Elephant apple, Curry leaves [*Murraya koenigii* (L.) Spreng.], Figs (*Ficus hispida* L.f.).	Mandarin Orange (*Citrus reticulata* Blanco), Lemon [*Citrus limon* (L.) Burm.f.], Papaya (*Carica papaya* L.), Banana (*Musa paradisiaca* L), Lichi [*Litchi chinensis* (Gaertn.) Sonn.], Jack fruit (*Artocarpus heterophyllus* Lam.), Pear [*Pyrus pyrifolia* (Burm.f.) Nakai var. culta (Makino) Nakai], Sapota (*Achras zapota* L.), Mango (*Mangifera indica* L.).	Indian jujube (*Ziziphus mauritiana* Lam.), Aonla, Lehsuwa/Gonda (*Corida myxa*), Ker (*Capans decidua*), Karaunda (*Carissa carandas* L.), Jamun [*Syzygium cuminii* (L.) Skeels], Date palm (*Phoenix dactylifera* L.), Mango (*Mangifera indica* L.), Bael (*Aegle marmelos*

TYPE	SEMI-ARID/SUB-HUMID	HUMID	ARID
			Correa ex Roxb.), Pomigranate (*Punica granatum* L.)
Cereals	Maize (*Zea mays* L.), Sorghum, Paddy (*Oryza sativa*), Wheat (*Triticum aestivum*), Pearl millet [*Pennisetum typhoides* (Burm.f.) Stapf & C.E. Hubbard], Finger millet (*Eleucine coracana*Gaertn.), Kodo millet (*Paspalum scrobiculatum* L.), Ragi, Barley (*Hordeum vulgare* L.), Ramdana, Small millets, Foxtail.	Paddy (*Oryza sativa*), Wheat (*Triticum aestivum*), Maize (*Zea mays* L.), Oat, etc.	Pearl millet [*Pennisetum typhoides* (Burm.f.) Stapf & C.E. Hubbard], Wheat (*Triticum aestivum*), Barley (*Hordeum vulgare* L.), Maize (*Zea mays* L.), Sorghum (Jower), Ramdana (*Amaranthus gangeticus*L.).
Oil Seeds	Sesame (*Sesamum indicum* L.), Linseed (*Linum usitatissimum* L.), Ground nut (*Arachis hypogaea* L.), Mustard (*Brassica juncea*), Soyabean (*Glycine max*. Merrill),	Rapeseed (*Brassica campestris*), Mustard (*Brassica juncea*),	Mustard (*Brassica juncea*), Sesame (*Sesamum indicum* L.), Taramira (*Eruca sativa* Mill.), Castor

TYPE	SEMI-ARID/SUB-HUMID	HUMID	ARID
	Safflower (*Carthamus tinctorvus* L.), Cotton (*Gossypium arboreum* L.), Coconut, Sunflower (*Helianthus annuus* L.), Niger (*Guizotia abyssinica* Cass.), Castor, Purging nut (*Jatropha curcas* L.), Rozal, Roselle (*Hibiscus sabdariffa* L.).	Groundnut (*Arachis hypogaea* L.), Sunflower (*Helianthus annuus* L.).	(*Ricinus communis* L.), Groundnut (*Arachis hypogaea* L.), Sesame (*Sesamum indicum* L.), Niger (*Guizotia abyssinica* Cass.), Safflower (*Carthamus tinctorvus* L.).
Pulses	Pigeon pea [*Cajanus cajan* (L.) Millsp.], Black gram (*Vigna mungo* (L.) Hepper), Green gram (*Vigna radiata* (L.) Wilczek), Cowpea (*Vigna catiang* Walp), Chick pea, Mothbean [*Vigna aconitifolia* (Jacq.) Marechal], Beans, Horse gram (*Dolichos biflorus* L.), pea (*Pisum sativum* L.), Lentil (*Lens culinaris* Medic.), Razama, Broad bean (*Vicia faba* L.), Khesari (*Lathyrus sativus*).	Black gram (*Vigna mungo* (L.) Hepper), Green gram (*Vigna radiata* (L.) Wilczek), Lentil (*Lens culinaris* Medic.), Khesari (*Lathyrus sativus*)..	Green gram (*Vigna radiata* (L.) Wilczek), Cowpea (*Vigna catiang* Walp), Chick pea, Mothbean [*Vigna aconitifolia* (Jacq.) Marechal], Guar, Black gram (*Vigna mungo* (L.) Hepper), Pigeon pea [*Cajanus cajan* (L.) Millsp.], Cluster bean (*Cyamopsis*

TYPE	SEMI-ARID/SUB-HUMID	HUMID	ARID
			tetragonoloba (L.) Taub.).
Root/Tuber Crops	Sweet Potato (*Ipomoea batatas* (L.) Lam.), Radish (*Raphanus sativus* L.), Carrot (*Daucus carota* L. var. sativa DC.), Asiatic yam (*Dioscorea alata* L.), Suram, Onion (*Allium cepa* L.), Garlic (*Allium sativum* L), Ginger, Haldi (*Curcuma* sp) Tapioca, Taro (*Colocasia esculenta* (L.) Schott), Potato (*Solanum tuberosum*L.), Ground nut (*Arachis hypogaea* L.), Yam [*Pachyrhizus erosus* (L.) Urban], Turnip (*Brassica rapa* L. emend. Metzger), Ginger (*Zingiber officinale* Rosc.), Beat root (*Beta vulgaris* L), Elephant Foot Yam (*Amorphophallus campanulatus* Blume ex Decne).	*Colocassia* sp., Potato, Yam, Cassava, Radish, Carrot.	Onion, Radish, Carrot, Sweet Potato, Cassava/Tapioca, *Dioscorea* sp.
Vegetables	Brinjal (*Solanum melongena* L.), Lady's finger (*Abelmoschus esculentus* (L.) Moench), Cluster beans [*Cyamopsis tetragonoloba* (L.) Taub.], Tomato (*Lycopersicon*	Gourd Family, Solanaceae Family, Brassica Family, French bean, Cowpea	Brinjal, Chilli, Tomato, Palak, Amaranthus, Cabbage, Cucurbits (Long

TYPE	SEMI-ARID/SUB-HUMID	HUMID	ARID
Vegetables	*ycopersicum* (L.) Karst), Cabbage (*Brassica oleracea* L.var.capitata L.), Cucurbits, Bitter gourds (*Momordica charantia* L.), Ridge gourds (*Luffa acutangula* (L.) Roxb.), Sponge gourds (*Luffa cylindrica* (L.) M.J.Roem.), Pumpkin (*Cucurbita moschata* Duchesne ex Poir), Amaranth (*Amaranthus gangeticus*L.), Common beans, Drumstick (*Moringa oleifera* Lam), Curry leaf tree (*Murraya koenigii* (L.) Spreng.), Spinach (*Spinacea oleracea* L.), Fenugreek (*Trigonella foenum-graecum* L.), Ambadi, Lablab, Multivitamin Checkurmanis, French beans (*Phaseolus vulgaris* L.), Cauliflower (*Brassica oleracea* L. var.botrytis L.) Knol-Knol, Cowpea (*Vigna catiang* Walp), Rai [*Brassica juncea* (L.) Czern & Coss.], Bathua, Snake gourd (*Trichosanthes anguina* L.), Winged beans (*Psophocarpus tetragonolobus* DC.).	(*Vigna catiang* Walp), Palak.	Melon, Water Melon, Ridge Gourd, Kachari, Chenopodium), Bathua (Lambs Quarters), Ivy Gourd, Sponge gourd, Lablab bean.

TYPE	SEMI-ARID/SUB-HUMID	HUMID	ARID
Spices/ Herbs/ Medicinal Plants	Chilli, Ginger (*Zingiber officinale* Rosc.), Turmeric (*Curcuma domestica* Valeton), Garlic (*Allium sativum* L.), Coriander (*Coriandrum sativum* L.), Shikakai, Sonamukhi, Ashwagandha, Tarota, Agheeda, Gokheeru, Dhatura, Nirgudi, Behuda, Hirda, Arjun [*Terminalia arjuna* (Roxb.) Wight & Arn.], Biba, Basak (*Adhatoda vasica* Nees), *Vinca rosea*, Turmeric, *Aloe vera*, Karpuravalli, Tulsi, Keezhanelli, Methi, Sauf, Onion, Pudina, Bay leaves, Mentha, Jatropa, Mother, Stevia, Ghievar, Vateh, Satawar, Safed Musali, Brahmi, Karanj, Touch me not, Neem (*Azadiracta indica* A.Juss), Citronella, Dill, Chillies. (*Trichosanthes anguina* L.), Winged beans (*Psophocarpus tetragonolobus* DC.).	Garlic, Turmeric, Ginger, *Lantana* sp., Tulsi, *Adhatoda* sp., Shaped Musli, Aonla, *Andrographis paniculata*, Ashwagandha.	Cumin (*Cuminum cyminum* L.), Fenugreek (*Trigonella foenum-graecum* L.), Isabgol, Coriander (*Coriandrum sativum* L.), Fennel, Ashwagandha, Guggal, Sonamukhi, *Aloe vera*, Tumba, Dhatura, *Lawsonia alba*, Tulsi, Drumstick (*Moringa oleifera* Lam), *Solanum* sp., Onion (*Allium cepa* L.)

TYPE	SEMI-ARID/SUB-HUMID	HUMID	ARID
Fodder/ Grasses	Anjan grass, Dheeman grass, Pipal leaves, Babool leaves; post harvested- Pigeon pea, Sorghum straw, Rice & Wheat Straw, Cotton Plants (young leaves and balls), Napier grass, Guniea grass, Agathy, Glyricedia, Subabul, Banana, Dhaicha, Barseem, Jower, Bajra, Maize, Cowpea, Centro, Dinanath grass, Desmodium, Desmanthes.	Napier, Oat, Guinae, Dinanath grass, Subabool, Maize (*Zea mays* L.), Cowpea, French beans (*Phaseolus vulgaris* L.), Lucerne, etc.	Bajra, Oat, Sorghum, Maize, Khejri, Ber, Sevan, Dhaman, Anjan (*Cenchrus* sp), Stylo, Butterfly Pea (*Clitoria ternatea*).