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Bio-Diverse Farming System Models for Dryland Agriculture

Central Research Institute for Dryland Agriculture
Hyderabad

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About this publication . . .

A farming system model encompassing crops, trees and livestock is the only option against climate change, recurrent droughts, loss of biodiversity and land degradation plaguing dryland agriculture. Such a bio-diverse system fulfills food, fodder, fuel and fertilizer requirements of the farm family, provides on farm employment and improves soil quality.

The prioritized regions under the predominant production systems of rainfed rice, oilseeds, pulses, cotton and coarse cereals including animals were identified. Suitable farming system models consisting of shrubs and trees species for various household requirements for prioritized locations are presented along with the specific soil and water conservation measures. A total number of 31 farming system models are described for 12 agro-eco sub-regions covering 52 priority districts and 47 selected districts.

Cover: Greening the grey areas

Designed by I. Ramamohan and KVGK. Murthy

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FOREWORD

Rainfed agriculture is being adversely affected by four-fold problems of land degradation, slow climatic change, degeneration of bio-diversity due to open grazing and poverty driven over utilization of natural resources. All these problems together lead to increasing challenges for sustainability of dryland crop production. These problems can be reversed, stopped, or at least reduced if the farming community can be motivated to adopt appropriate technologies developed by the National Agricultural Research System (NARS). This is possible only if an economy driven enterprise is the template of the farming system in vogue in these areas. This means that a farmer should receive higher and staggered income from the holding. A bio-diverse multi-tier system of farming can thus be the answer. This system envisages a coupling of multipurpose trees, horticultural plants, health herbs, food/ oilseeds/ pulses, etc., with livestock rearing. For this system to survive, efficient rain-water conservation and utilization is the central task. The tangible benefit from this system could be the efficient nutrient and hydrological cycling, which can impart resilience by building soil quality with time. Such a multi-tier system can create a suitable microclimate for crop growth in an Oasis of climatic change. The staggered income is envisaged from the annual crops and livestock periodically from the horticultural plants of short duration species, on long duration from woody species and from the bi/tri annual species and others in the system. Needless to say that such an approach will generate greater employment and valuable heritage for posterity to build upon.

This bio-diverse farming system is superior to growing avenues of forest species; pasture species etc. based on land capability alone. It has the capacity of islands of optimized microenvironment when coalesced can completely change the landscape. Thus, superiority for this bio-diverse model exists over land capability based models.

In this compilation, an effort has been made to identify multi-tier system for prioritized regions under the predominant production systems of rainfed rice, oilseeds, pulses, cotton and nutritious (coarse) cereals in practice in the Rainfed agro eco system. Suitable species for biofencing, other important needs etc., along with specific region based soil conservation measures are described which shall provide a ready reckoner. Needless to say that the information included covers the Indian national agricultural research system on agro-forestry research along with the contributions from All India Co-coordinated Research project for Dryland Agriculture network. I congratulate Dr.K.P.R. Vittal, Project Coordinator and his colleagues for their monumental efforts summarized in the models presented in this document.

HP. Singh
Director

Contents

1. Introduction

Unabated land degradation due to nutrient mining combined by topsoil loss by water erosion and climatic change towards adverse conditions are the serious problems affecting the dryland agriculture. In this connection, an early action is to be taken by controlling erosion, replenishing the soil with high biomass for revitalizing the various soil processes and creation of congenial microenvironment. Invariably this will improve the soil resillence, quality and mitigates the drought affect. The practice that is needed is the resource conservation and utilization based template created by using perennial, semi-perennial and annual plants. This knits the farmers to the land and generates employment much of the year. Use of cash returning species will improve the socio economic conditions of the farmers. A farming system model cutting across the production systems and agro eco sub regions is envisaged hereunder based on research data, and experience in the drought prone blocks.

1.1 Climate Change-A new challenge to the sustainability of dryland agriculture

Climate change has become a great concern and attracted the attention of all nations in the world. The most important aspect is the increase in global average air temperature, which is primarily ascribed to the increased combustion of fossil fuels, and land use changes through intensive agriculture and urbanization. In India the warming period is observed in post monsoon and winter seasons with little variation during monsoon season. The projected change for India is that the increase in temperature is likely to be less in *kharif* than in *rabi* season. The *rabi* rainfall may exhibit large uncertainty whereas *kharif* rainfall is likely to increase by as much as 10 percent. Such global climate changes will affect agriculture considerably through its direct and indirect affect on crops, cropping systems, livestock, pests and diseases, weeds, etc., threatening the food security. Thus, dryland agriculture and its productivity totally rely on agro climate and its changes with time. Any change in the rainfall affects the performance and sustainability of cropping systems, soil resilience and water balance. In the absence of support of assured irrigation, the affects are more pronounced. A trend analysis of five yearly moving average annual rainfall in the last century and its variability provided the following picture for some of the All India Co-ordinated Research project for Dryland Agriculture centers:

Average annual rainfall	Variability of Annual Rainfall		
	Decreasing	Stable	Increasing
Decreasing	Akola	Agra	Bangalore
	Rajkot	Indore	Varanasi
	Anantapur	Rewa	Jhansi
Stagnant		Kovilpatti	Bellary
		Bhubaneswar	Hisar
			Ranchi
Increasing		Ludhiana	Jodhpur
		Udaipur	Solapur
		Rakh Dhiansar	Bijapur

The critical region is where rainfall is decreasing and variability is increasing. Even in the other forms of variability, a decrease in the annual rainfall still worsens the situation. Hence, microclimate change needs to be brought about by agroforestry, afforestation, etc. to ensure favorable conditions. Under stagnant rainfall higher land productivity can be obtained by crop diversification including alternate land uses. With increasing rainfall the cropping intensity can be tailored to the rainfall trends. An interesting feature is that at Bijapur the rainfall has been increased in the last 100 years by about 200 mm. The recommendation of contour bunding with time has been replaced with compartmental bunding unknowingly to fit the climatic changes. Thus the water harvesting and reuse along with *in situ* conservation needs attention. For sustaining the subsistence agriculture, a holistic multifarious self reliant farming system knitted to land productivity is the present day need.

1.2 Setting

Influenced by the aftermath of green revolution, small farmers have changed from their traditional farming methods to intensive cultivation using only one or two species and relying on the market for chemicals, seeds and other inputs. Many of the problems they face at present are due to mismanagement of the land. Poverty and insecurity are very closely linked to soil degradation and diminishing natural resources, besides the less endowed ecological situations. The solely money driven agriculture has resulted changes in the cultural ethos of the community and irreversible damage to the time tested sustainable agricultural practices (National Research Council1989). Some of the indicators are –

- The economics driven monocropping patterns have destroyed the crop diversity thus making an adverse effect on the agro-ecosystem (Norman 1968).

- Even small holders are going in for hiring for land preparation. This is further accentuated by increasing the labour rates. Mechanization (Banta1973) of small farm operations coupled with easy availability and application of chemical fertilizers seem to be having a negative impact on the choices of the farmers in keeping livestock. However, small farmer to a great extent depend on livestock to meet most of their requirements in terms of manure production, draft power and milk production.

- In place of draft cattle, milch bovines are on increase. This is leading to more and more involvement of family labour in dairy and related activities. They generally do not produce their own fodder and fuel wood, but rely on forest areas that are already with a poor canopy cover.

- At least for six months in a year there is no vegetal cover on cultivated soil. The hot sun dries the topsoil, creating a hard, impermeable layer leading to poor infiltration of the rainwater. The stubbles of the crops cannot sufficiently reduce the movement of water and it will flow carrying the top fertile soil, leaving reduced or little moisture behind.

In a low-cash system, diversity of production seems directly related to farmer welfare. If farm size is small and resources are limited, improvement of farmer welfare in rainfed agriculture may require emphasis different from what we have given in the past in the green revolution.

It is not too late to realize the potential for improving the rainfed agricultural scenario through enhanced biomass production by adopting multiple trees based farming systems (Teague and Lee 1988 and Grewal 1988), with integration of livestock thereby making it sustainable. There is a need to adopt suitable cropping systems, which are ecologically sound, economically viable and strictly acceptable. The systems approach is illustrated as a “horizontal” one, going across the entire cropping pattern. Components of the system may be researched, discipline wise, but still within the framework of the entire system. Animals, however, can be devastating to diversity of cropping on the farm if grazing is uncontrolled. The price for uncontrolled grazing is generally paid by the small farmer who has no animals and whose crop options are severely limited by the animals.

The traditional agricultural system was a slash and burn system. The later can, in fact, be classified as an agroforestry system, because woody perennials and agricultural crops are combined in a rotation. This slash and burn system is still in practice in NE Region. It is only of late, due to the present population pressure this way of cultivation is considerably reduced. Of late researchers are suggesting that planting trees on

croplands and thereby increasing biodiversity as a possible solution to many problems small-scale farmers face. There are many benefits for the farmers, both direct, economic benefits, and indirect, ecological benefits. Some soil fertility, crop based, and diversification related issues are highlighted.

1.2.1 Soil fertility related issues

Over a period of time farming systems have evolved in semiarid tropics to suit the requirements for maintaining soil fertility and production related issues. Any land development programs addressing soil and water conservation issues should essentially take into consideration these farming systems in practice in order to have lasting effect. The nutrient flow studies indicate how important these factors are in maintaining the health of farmland (Narain 1986). The involvement of farmer on a day-to-day basis by integrating other farm enterprises into the farming systems will enable the farmer to put on their lands through out the year. The soil and water conservation measures coupled with vegetative cover on the agricultural lands should provide fodder and fuel, shade and shelter, wind break effect through vegetative barriers, and sustain livestock etc., in order to provide livelihood security to the farmers.

The complexity is also dictated by the plurality of the livelihood options exercised by the farming community. This plurality is also a coping mechanism evolved over a period of time to adjust to the uncertain cropping in semiarid tropics. It is to be appreciated that any attempt to simplify the farming systems with a tendency towards monocropping will have adverse effect on the farm nutrient balance making the farming operations unsustainable over a long run. It is also to be noted that in any given region the farms are not identical in terms of the complex interrelationship between various farming enterprises that are established and sustained over a period of time.

1.2.2 Crop based issues

Rainfall in India typically occurs in two peaks, first peak in June-July and the second peak in September-October. Cropping systems were eveolved to utilize the moisture available through out the rainy season. Hence the choices that were available to farmers many times ran into dozens. Very few crops were cultivated as single crops. Most of the farmers practiced mixed crops with options for several cereals, several pulses and fodder. These crops were evolved not only to suit to the uncertain rains but also to provide the most needed nutrition both to humans and animals at the household level.

The economics driven changes in monoculture operations, even in scientifically managed areas, have led to very unsustainable options. Though these changes directed

by policy help to a great extent to meet the national level requirement in terms of food grain or oilseeds production, often they may not be in the long-term interest of the farmers. Further, most of the technologies promoted by the recently implemented watershed development programs do not seem to be very sensitive to the issues of farming systems and interdependence of various farming enterprises. Small farmers and agroforestry affect mechanization in cropping systems (Banta 1973).

1.2.3 Issues of diversification

The dynamics associated with changing crop choices and impacts are complex. People often prefer wider choice of foodstuffs in their nutrition. Indigenous technical knowledge in several villages permits the families utilize 20 to 30 different plant products from a field of only 0.5 to 1.0 hectare, including a number of uncultivated foods.

Important risk distribution measures include farm diversification. Small farmers (1-2 ha of land covering different types of less economic holdings) tend to accumulate savings through trees grown (Bheemaiah, Subramanyam and Syed Ismail. 1995 and Jama and Getahun 1999) in the farmstead, backyard poultry, a few ruminants and or bovines etc. These farm enterprises are also complimentary to each other and provide very stable and diverse livelihood options to the farmers. Any measures taken up at the farmers level for soil and water conservation must essentially address these intricate farm diversity aspects failing which farmers may not be in a position address the requirements for optimum soil conservation measures.

Agroforestry, however, calls for special attention in certain areas (Osman and Rao 1999; Reddy and Sudha 1988) especially in arid (Shankarnarayan, Harsh, and Kathju 1987). First of all an agro-forestry system, which is suitable for one area may not be suitable for another region. The fact that agroforestry is a more complex system than single-crop farms means that farmers need to be willing to spend more time on their field and adopt to the new ways of living by learning the necessary techniques.

Earlier agroforestry was synonymous with alley cropping. This approach met with no success. The International Council for Research in Agro-forestry (ICRAF) and other agencies broadened the very concept. Agroforestry is a relatively new name given to an approach to cultivation, which has been used by many people all over the world, in many different ways. It is a collective name for land use systems in which woody perennials are grown in association with herbaceous plants (crop, pastures) or livestock, in a spatial arrangement, a rotation, or both, there are usually both ecological and economic interactions between the tree and other components of the system (Solanki

and Ram Newaj 1999). The redefined agroforestry model is unique as it focuses on assisting farmers in creating a situation where they are managing their own natural resources including livestock in a sustainable productive way, and making them less dependent on outside labour and forest areas. To prevent runoff and soil erosion and to meet all the requirements in terms of fodder resources and soil cover, efforts must be made to obtain them from integrated farming system only. The cropping system must permit limited grazing. Sufficient loppings should be available from the farmstead. Micro level farming systems are practicable only in rainfed lands due to resilience in adoption of diversification from crop through tree to animal.

The scenario can be summarized as follows:

Issue	**To upgrade ecologically degraded and stressed environment**	
Indicators	Soil quality deterioration	Debt trap and poverty
Problems	Poor fertility Loss of biota Water stress Ground water depletion	Poor labour productivity Less marketing facilities Migration for employment Lack of policy support Bigger family size
Means	Agro-biodiversity, Large biomass, C sequestration / microbes / Low till / Compost Canopy cover, Litter / mulches, Exogenous inputs (?)	Graded Technology On-farm omnibus R&D Agro-industry
Strategies	Alternate land use, Nutritional security, ITK, MPTs, Home remedies Seed to market	Post-harvest value addition, Agro industry, Market Intelligence, Weather advisories
Mode	Self service	Cyber netting
Solution	Adoption of Integrated bio-diverse Mixed Farming System in Small Holdings in Rainfed areas	

Since farming systems are highly environment-specific, order must be brought to their study by categorizing types of systems and relating them to their environments. Such physical parameters as water availability, soil tillage characteristics, and temperature, as well as the socio-economic parameters of farm size and market availability determine farming system types. In classifying areas however, caution must be used. Climatologists and Soils experts should plot gradients of critical parameters rather than fixed 'zones' of their work in locating farming system types. As technology changes, the boundaries of agro-climatic zones change. A summary of the amount and duration of rainfall, above and below fixed limits, plotted over a geographical area permits fitting different cropping patterns to specific areas, while pre-conceived 'zone' assumes that this has already been done (CRIDA 1997. Vision 2020).

2. Farming System Model

Various components for integration are

- Parkland systems
- Trees on bunds
- Wind breaks
- Silvi-pasture system
- Agrohorticulture system
- Block plantations
- Economic shrubs
- Live fences
- Crops + green leaf manure species (mixed/intercrops)
- Integrated animal based systems- Fisheries, Dairy, Piggery, Small ruminants, Poultry, Apiary

For purposes of description and study, a farm can be divided by space and time factors into different enterprises, each having its own resource requirements and productivity pattern. This system includes all activities, either on or off the farm, that use farm resources. Most enterprises of the system are interrelated. The layout of the farm varies in response to many social factors (Grimble 1973, Ruthenberg 1971, National Research Council 1989 and Harwood 1974) and selection of models.

Nutrient management efforts undertaken in isolation of the farmers' livelihood strategies and coping mechanisms evolved over generations may not succeed. The narrow sectoral approaches to crop cultivation separating livestock should lead way for more integrated farmer centered approaches. Generating more options for the farmer to attach more to the land is the ultimate key required to ensure adequate production of biomass and integrated nutrient management. Several tools are available for this. Important among these is the farming systems approaches. For planners, policy makers and organizations concerned with integrated nutrient management, farming systems approach can be a real challenging option.

A brief summary of the various components of farm enterprises may be useful in studying their interaction with the major cropping systems.

2.1 Live fence rows:

Fencerow areas are important in most uplands of small farm size in South-east Asian countries. They are usually planted to a species of legume (*Leucaena leucocephala* or *Sesbania grandiflora*) in wet areas and Zyziphus, *Hibiscus, Glyricidia* etc. species in dry areas (Korwar and Radder 1994). The former serve as a source of human food and animal feed, with leaf protein approaching 6 per cent. All are used for firewood and green manure. They are cut annually to a height of 1.5 meters, from which new shoots emerge each year. These species are ever present and an important part of small-farm agriculture. The fencerows may include other economic trees such as mango or kapok. Often they are planted to a grass species, such as *Saccharum spontaneum*, which is useful for fiber and for thatch. This species does not spread to cultivated fields. Such fencerows are used in areas of seasonally high rainfall to control erosion as well as to separate fields. The diversity of plants in them and their effectiveness in controlling erosion are highly dependent on the animal systems. Uncontrolled grazing minimizes the effectiveness in controlling erosion are highly dependent on the animal systems.

In developed countries the existence of hedgerows are described as restricting mechanization and also in providing shelter for various insect pests as well as being a source of weeds. On small farms, however, mechanization is small-scale and not likely to be impeded (Banta 1973). The insect relationships of fencerow areas are open to question. Some workers feel that the increased diversity of insect species resulting from diversified cropping results in a more stable pest pattern and one that is more easily managed. Weeds in most well developed fencerows are excluded by the planting of desirable grass species and by controlled grazing. The fencerows have much to offer the small farmer as long as it does not interfere with small farm implements or water distribution.

2.2 Cropping Patterns

The attention in institute programs is focused on cropping patterns as the key aspect of farming systems. This is also reflected in the theme cropping systems of National and International Agricultural research Systems. This does not belittle the fact that cropping patterns interact closely with other farm enterprises, but indicates that attention is being focused on their improvement in the context of other farm enterprises.

Tree crops are common to most farming systems providing an element of stability to the system in areas of highly variable rainfall. Mangoes, and other drought-tolerant

species characterize the low-rainfall areas. Long-duration annuals such as pigeonpea serve essentially the same purpose, but are higher in productivity. Most farming systems consist of a combination of these and other crops enterprises, which field-crop sequence patterns accounting for the bulk of farm productivity. Many aspects of crop management technology are closely related to the type of cropping pattern, making a systems approach essential to the successful development of new technology (Bantilan *et al* 1974 and IRRI 1974).

Most farmers, when designing their systems use a combination of enterprises having different resource requirements. Some may be of lower productivity but lend stability to the system. Others may be labor or cash-intensive and highly productivity, but unstable from the biological, management or economic standpoint. The net effect is to balance the farmer's resources in meeting his needs for productivity and stability. As farm size increases, the labor constraint dictates a change in cropping pattern to less labor-intensive crops. Broadcasting in these cases may become handy.

2.3 Animal Systems

Animals on the farm interact with all other farm enterprises. They require considerable labour for tending as well as a year-round source of feed. Cropping patterns must be adjusted to meet these needs. Some of the interactions are quite precise, as the crop animal interaction of a Philippine system. The cropping pattern is rice followed by maize in a 1500 mm, 6-month rainfall pattern. When the maize is harvested, the chicken population is markedly increased to use the available feed. The chickens are sold just after rice planting the next year in time to provide cash for nitrogen fertilizer, the major input for growing rice. Animals also, of course, supply power for farm operations. They also tend to add stability to the system, as their productivity generally does not fluctuate as widely in response to weather as does that of the crops.

2.4 Farmstead area

Diverse mixtures of annual and perennial crops characterize the farmstead area. Its function is both an aesthetic and economic. A well-developed homestead area provides a year-round flow of small income and a source of food and nutritional security. Its extent and productivity depend on the style of village commands, the number of small and large ruminants. Lowland areas of South-east Asia, have far smaller homestead areas than do the scattered dwellings common to upland areas. Untended grazing animals such as goats and cows greatly reduce the variability and productivity of these

areas. Since most of the plants are trees or shrubs, this area lends biological and management stability to the overall system (Grimble 1973).

2.5 Non-farm enterprises

These are enterprises conducted either on or off the farm but which do not utilize much of the agricultural land resource. These include activities, such as cottage industries, off-farm employment, contract tractor or animal work, or any activities, which use the farm's human or physical resources and provide a return in the form of cash, kind or security. These activities influence other farm enterprises and thus become an important aspect of the system.

When agro-climatic conditions have been described, which determine specific types of farming systems, research can begin on complete systems within those environments. The institute is located in a representative site. Components of the systems, however, may be researched outside the area at a location where relevant conditions can be simulated. Water-use studied, for instances, may be conducted in simulated environments at research centers.

2.6 Description of model:

The model is –

- On one hectare roughly 600-700 MPTs and one hundred fruit trees may be planted to serve enough fuel wood, fodder, compost material and cash income for a family of five. The objective of the model is to reduce the dependency on forest resources and wage labour. Depending on agroclimatic conditions the number of trees per hectare and the selection of fruit and forestry species may vary. Mango was by far the most popular fruit tree and forestry species with high growth rates or strong wood were preferred, for example Eucalyptus, *Tectona grandis, Acacia auriculiformis, Casurina equisetifolia and Cassia siamea* are some of the favoured species.
- It is important to keep grazing animals and passers-by off the land. Hence the importance of creating thick live hedges, those can be pruned regularly and provide fodder for livestock or composting material.
- Self-sufficiency of foodgrains is another objective of the model and the use of intercrops as well as high yielding varieties was promoted. To increase the soil fertility cost efficient technologies such as NADEPP and vermicomposting may be

introduced. Use of PSB and Rock phosphate may require attention. (Various systems were developed and practiced worldwide on organic farming. Significant among them are - Howard system – Balfour Organic – UK; Biodynamic system – USA; Rusch Muller Organisch – Bioloigical – Germany; Lemaire – Boucher/France; Regenerative – USA; Natural Farming – Japan; Permaculture – Australia.)

- The area would be systematically treated with field bunds across the slope. The trench cum bund created help to retain soil and moisture *in situ*. This also would promote good tree growth of various species planted on the bunds. Every field bund is covered with MPTs planted at a close spacing of 1 to 2 m in a row. The MPTs comprise of species such as teak, *Subabul, Acacia, Gliricidia, Dalbergia, Casia, Casurina* etc. Approximately 500 to 1000 plants per hectare are to be accommodated on boundaries and bunds. These plants are regularly pruned to avoid shading and to obtain biomass for mulching and fertilizing. The twigs pruned also provide enough fuel wood to meet the firewood requirement of the local community.

- Fields are covered with live fencing using species such as *Cassia siamea, Gliricidia*, *Euphorbia*, *Vitex nigundo, Pongamia* etc. They provide manure and their decoction botanical pesticides. It may be noted that usually a farmer accepts a plant only when it has multiple utilities. These live fences in addition to providing protection to the plantations also help to increase bio-diversity in the area and produce substantial quantities of biomass. This biomass obtained by pruning the fencing regularly which helps in increasing soil moisture retention capacity and increased fertility.

- The water harvesting should be both runon-runoff based. Farm ponds are opened at strategic locations to harvest excess runoff from the fields. These ponds help increase in percolation. The increased percolation leads to maintenance of better soil moisture regime, which in turn helps better tree growth. On the contrary farm ponds are sealed to integrate fish and poultry as per needs

- Dryland horticulture species such as Mango, Tamarind and Cashew are promoted at a rate of 100 plants per hectare. The fruit species shall be a mix, both as varieties and species for enhanced availability of fruits during the year.

- Livestock will be an integrated component. The form of livestock may vary from region to region. The number of animals is to be kept as low as possible meeting essentially home needs of the farmer and very little towards commercial activities. The browsable species is to be fed to the cattle by mostly stall feeding, except

in pasture plots. Silaging will be the method for off-season needs. The non-browsable species will be converted into compost.

- The farmyard manure and silt accumulated in the farm ponds will be recycled. Instead of spreading too thinly, a method will be designed in consultation with farmers as per the requirements to enrich different areas and covering the entire land in due course of time.

The above measures may result in congenial microclimate reducing aridity and crop losses due to moisture stress and result in increasing agricultural crop production due to –

- Better soil moisture regime
- Increased soil organic matter
- Windbreak effect due to live fences and tree plantation leading to better soil moisture retention and reduced transpiration
- The farmer occupied with land based activities for extended periods.
- Staying back on his land almost 12 months in a year and hence takes better care of land.
- Increased biomass availability helping in integration of livestock into the farming systems
- The horticultural trees providing sustained incomes even in bad rainy season thereby providing an insurance cover against fluctuations in crop production.

The successful incorporation of tree component into farming systems in the program result in visibly improved protection to the watershed. This helped us to conceptualize a new approach to watershed treatment, with more thrust on permanent vegetation in agricultural fields.

3. Identification of priorised districts for sustainable farming system models

3.1 Rainfed production system details – Agro eco region wise:

The agro eco region (AER) based rainfed area under different production systems was arrived after identifying the rainfed area of all the districts for the period of 1990-95. Information on extent of total fruits and vegetables (irrigated and rainfed) and livestock numbers are also given. Information from western Himalayas, cold arid (AER 1), eastern Himalayas, warm per humid (AER 16), north eastern hills, warm per humid (AER 17), and hot humid to per humid island (AER 20) ecoregions was not used. The selected area covers about 81 mha covering 16 states out of estimated 90 mha rainfed area in the country.

Rainfed area ('000 ha) in a Production system (1990-95)

AER	Crop based Production system ('000 ha)					Total Rainfed area ('000 ha)	Total Fruits and Vegetables ('000 ha)	Livestock (Nos. in 000)
	Rice	Oilseeds	Pulses	Cotton	Cereals			
1.	—	2220	3314	—	6236	11770	95	37378
2.	—	2123	1800	—	—	2123	52	6681
3.	55	2482	739	943	1963	7242	550	66548
4.	—	3730	344	319	1935	6723	175	23601
5.	344	—	909	2980	14517	18184	458	41676
6.	—	2468	82	—	515	3892	369	22771
7.	48	2066	262	280	2098	4573	517	35443
8.	1094	50	2383	—	758	2164	435	34242
9.	2666	2035	—	359	327	7771	132	23314
10.	2664	283	1634	—	108	3054	101	13012
11.	4960	374	—	—	783	7751	1345	31197
12.	1832	—	—	—	1354	3186	360	25255
13.	—	—	—	—	398	398	9	3805
14.	1217	37	—	—	—	1254	10	3012
15.	—	—	—	—	—	—	—	—
16.	—	—	—	—	—	—	—	—
17.	133	—	29	—	—	163	3	710
18.	1428	—	—	—	316	1743	177	7183
19.	—	—	—	—	—	—	—	—
Total:	16439	17868	11495	4880	31308	81990	47893	75828

For rice AERs 9-13, oilseeds AERs 2-5, 7 &12, pulses AERs 2, 4, and 8-10, cotton AER 5, Nutritious cereals 2, 4-6, 8-9, and 14 are important rainfed areas.

3.2 Prioritisation:

An attempt has been made develop sustainable farming system models for rainfed agro-eco system in India. The process involves

- Identification of rainfed cropping region for major production systems (Rainfed rice, oil seeds, cotton, pulses, nutricious cereals) of rainfed agro- eco system
- Identification of priority districts from the list of dominant districts identified for each of the production system based on soil degradation status
- Development of sustainable farming system models for each of the districts and for the agro-eco sub region covering these districts.
- Farming system models are also developed for the agro-eco sub regions which are not having any of the priority districts by synthesing the information available from AICRPDA centers and other literature

Details of this process are given below.

1. Identification of rainfed cropping region

   Though the rainfed area distribution is wide spread, but a few districts contain most of the area. The area under districts for each of the production sytem was arranged in descending order according to the area covered. The production systems considered for the study are Rainfed rice, oil seeds, cotton, pulses, nutritious cereals. The districts covering 85% of the cropped area for a particular crop were selected and recognized as a cropping region. Thus, dominant districts for each of the production were identified.

2. Dominant districts under each production system were classified based on soil degradation map of India (NBSSLUP, 1994) using the following criteria
   1. Water erosion with very high severity
   2. Water erosion with High severity
   3. Water erosion with Medium severity
   4. Physical deterioation waterlogged areas High severity
   5. Physical deterioation waterlogged areas Medium severity
   6. Chemical deterioration loss of nutrient – High severity

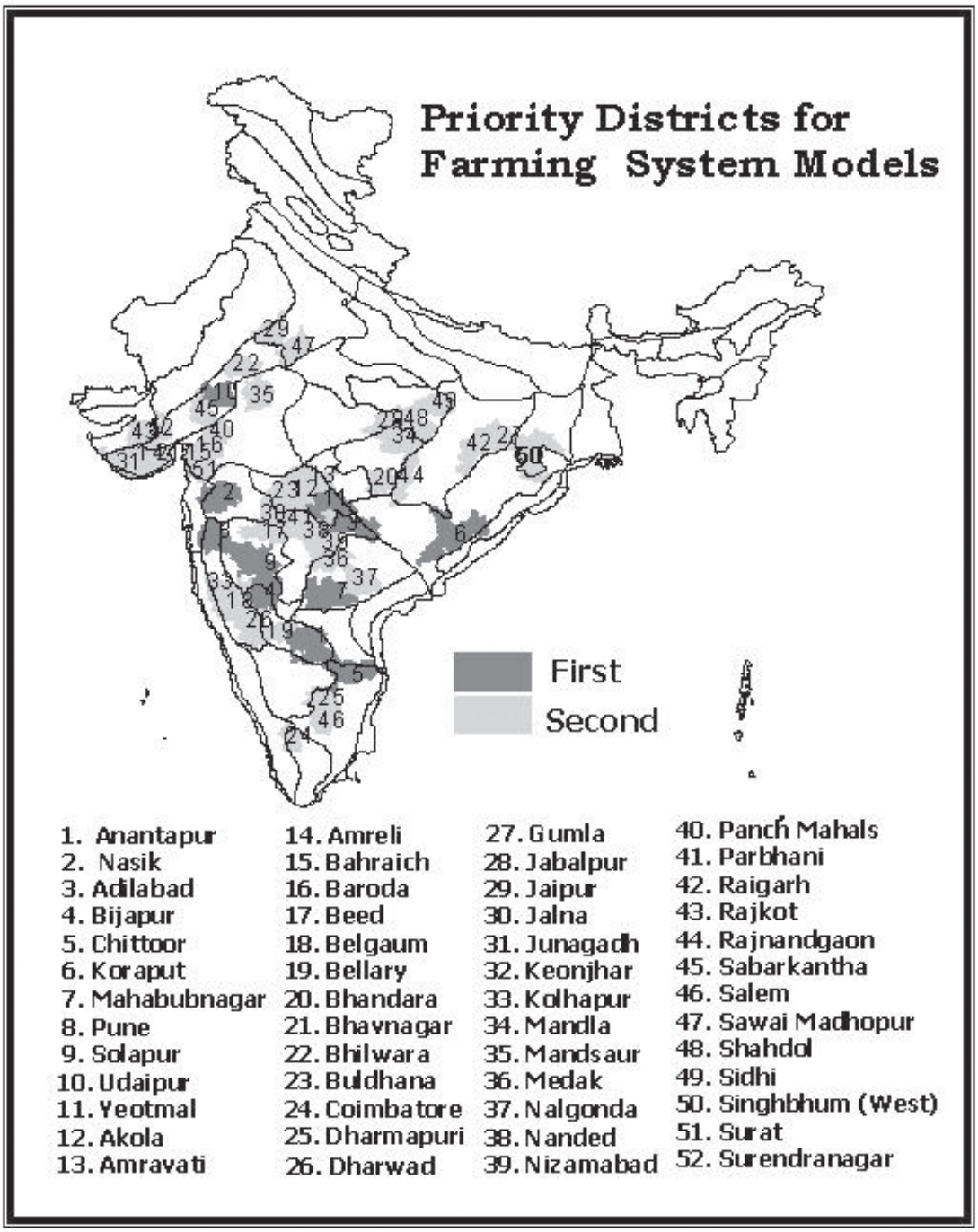
7. Chemical deterioration salinization – High severity
8. Chemical deterioration salinization– Medium severity

3. For each of the Production System, districts falling under the S.No. 1&2 were considered as high priority areas and the remaining districts under S.No. 4 - 8 are given lower priority. Priority districts thus identified for each of the production system have been merged together to identify the priority districts for the entire rainfed agro-eco sysyem as a whole. Map depicting the districts for high priority and low priority districts for rainfed agro-eco system is given in the next page.

   The priority districts are considered for development of sustainable farming system models so as to reduce the further soil degradation (Figure).

4. Sustainable farming system models covering the priority districts and for each of the agro-eco sub region are developed.

   Information on the suitable farming system models for each of the agro-eco sub region and districts under each of the Agro-eco sub-regions (AESR) with priority status are described in the following pages. However, the interactions among these components when integrated into a farming system depends on many factors viz. rainfall, soils, management and the quantum of the components themselves.


Priority Districts for
Farming System Models
First
Second
1. Anantapur
2. Nasik
3. Adilabad
4. Bijapur
5. Chittoor
6. Koraput
7. Mahabubnagar
8. Pune
9. Solapur
10. Udaipur
11. Yeotmal
12. Akola
13. Amravati
14. Amreli
15. Bahraich
16. Baroda
17. Beed
18. Belgaum
19. Bellary
20. Bhandara
21. Bhavnagar
22. Bhilwara
23. Buldhana
24. Coimbatore
25. Dharmapuri
26. Dharwad
27. Gumla
28. Jabalpur
29. Jaipur
30. Jalna
31. Junagadh
32. Keonjhar
33. Kolhapur
34. Mandla
35. Mandsaur
36. Medak
37. Nalgonda
38. Nanded
39. Nizamabad
40. Panch Mahals
41. Parbhani
42. Raigarh
43. Rajkot
44. Rajnandgaon
45. Sabarkantha
46. Salem
47. Sawai Madhopur
48. Shahdol
49. Sidhi
50. Singhbhum (West)
51. Surat
52. Surendranagar

4. Suggestive Biomass Producing Farming System Models

4.1 Model : Tree farming/ Pasture management in Semi-arid – *kharif* and *rabi* vertisols

Region : Western plain, Kachchh and part of Kathiawar Peninsula, hot arid eco-region: Marusthali, hot hyper-Arid with shallow and deep sandy desert soils, very low available water holding capacity (AWC) and length of growing period (LGP) < 60 days. (AESR 2.1)

Target Districts:

First Priority: -
Second Priority: -
Selected districts: Bikaner, Barmer, Jodhpur

Farming system model:

Crop Production System: Maize, Sorghum, Sesame

Boundary plantation: *Tecomella undulata, Prosopis cinararia.*

Live fence

Outer Layer: *Zyzyphus mauritiana*, Cactus
Inner Layer: *Parkinsonia aculeata*

Trees on crop lands

Fodder/green biomass: *Prosopis cineraria, Pongamia, Tecomella undulata, Dichrostachys cineraria, Cassia siamia, Acacia nilotica*
Fruit: Ber, Datepalm, Fig, Jamun, Phalsa
Wood (Commercial/Farm Use/Fuel Wood): *Acacia tortilis, Parkinsonia aculeata*

Medicinal & Aromatic Plants: *Plantago ovata, Cassia angustifolia*, Safed musli

Vegetables: Clusterbean, Cowpea, Water melon, Round melon, Long melon

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Sheep, Goats

Water harvesting techniques: Manage in<10ha watersheds: More emphasis on *in situ* water conservation: Increasing soil infiltration capacity and reducing soil crusting problem:Contour furrowing: Absorption terracing: Contour trences: Land Surface treatment to increase soil water profile storage: Inter-row water harvesting: Inter-plot water harvesting of 1:1 cropped to uncropped land: Dead furrows at 3.6 m intervals:Gully control: Soil water balance studies: Runoff-erosion measurements.

Soil and Water Conservation Practices: Increasing catchment area: Designing catchment size for farm ponds under low runoff conditions: Water use for life-saving irrigation: Efficient use of stored water.

Groundwater Exploration: Fluctuation of groundwater levels in low runoff area: Exploring ways of collecting more runoff to recharge soil profile.

4.2 Model : Tree farming- silvi pasture in Marginal and semi *kharif* ardisols in Arid Region

Region : Western plain, Kachchh and part of Kathiawar Peninsula, hot arid eco-region: Rajasthan Bagar, North Gujarat Plain and South-Western Punjab Plain, hot typic-arid with deep, loamy desert soils (inclusion of saline phase), low AWC and LGP 60 – 90 days. (AESR 2.3)

Target Districts:

First Priority: -

Second Priority: -

Selected districts: Pali, Hisar, Mahendragarh, Bhiwani

Farming system model:

Crop Production System: Pearl millet, Moth bean

Boundary Plantation: *Prosopis cineraria, Acacia tortiles, Eucalyptus*

Live fence

Outer Layer: *Prosopis juliflora, Zizyphus mauritiana, Zyziphus numularia,*

Inner Layer: *Dalbergia sissoo, Carissa carundus*

Trees on crop lands

Fodder/green biomass: *Prosopis cineraria, Tecomella undulata,* Pongamia, *Hardwikia binata, Cassia siamea, Calopospermum mopane, Azadirachta indica*

Fruit: Ber, Date palm, Jamun, Fig

Wood (Commercial/Farm Use/Fuel Wood): *Acacia tortiles, Acacia senegal, Acacia cupressi formis*

Medicinal & Aromatic Plants: *Plantago ovata*, Safed musli, *Cassia angustifolia, Papaver somniferum.*

Vegetables: Cluster bean, Cow pea, Long melon, Round melon, Okra.

Water harvesting techniques: Increasing soil infiltration capacity and reducing soil crusting problem: Land Surface treatment to increase soil water profile storage: System of land shaping into compartments to store more water in the soil profile: Inter-plot water harvesting of 1:1 cropped to uncropped land: Dead furrows at 3.6 m intervals: Dune stabilization; sub-surface moisture conservation : Soil water balance studies: Runoff-erosion measurements.

Soil and Water Conservation Practices: Designing catchment size for farm ponds under low runoff conditions: Efficient use of stored water.

Groundwater Exploration: Fluctuation of groundwater levels in low runoff area: Exploring ways of collecting more runoff to recharge soil profile.

4.3 Model : Tree farming/ silvipasture in Arid to semi-arid orthids - vertisols in Arid Region

Region : Western plain, Kachchh and part of Kathiawar Peninsula, hot arid eco-region: South Kachchh and North Kathiawar Peninsula, hot arid with deep loamy Saline and Alkali soils, low AWC and LGP 60 – 90 days. (AESR 2.4)

Target Districts:

First Priority: -

Second Priority: Rajkot, Surendranagar

Selected districts: -

Farming system model:

Crop Production System: Groundnut, Pearl millet, Sorghum

Boundary Plantation: *Prosopis cineraria, Acacia nilotica,* Lawsonia

Live fence

Outer Layer: Opuntia sps., *Lawsonia alba, Ziziphus mauritiana*

Inner Layer: *Prosopis cineraria, Pithecalobium dulce, Parkinsonia aculeate*

Trees on crop lands

Fodder/green biomass: *Dichrostachys cineraria, Pongamia pinnata, Tecomella undulata, Azadirachta indica, Dalbergia sissoo*

Fruit: Custard apple Mango, Pomegranate Phalsa, Fig, Jamun, Tamarind

Wood (Commercial/Farm Use/Fuel Wood): *Acacia senegal, Acacia nilotica,* Eucalyptus sps.

Medicinal & Aromatic Plants: *Plantago ovata, Cassia angustifolia*, Liquorice.

Vegetables: Cowpea, Cluster bean, Brinjal, Okra, Long melon, Drum stick.

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Sheep, Goat

Water harvesting techniques: Increasing soil infiltration capacity and reducing soil crusting problem: Land Surface treatment to increase soil water profile storage: System of land shaping into compartments to store more water in the soil profile: Inter-plot water harvesting of 1:1 cropped to uncropped land: Dead furrows at 3.6 m intervals: Dune stabilization: Sub-surface moisture conservation: Soil water balance studies: Runoff-erosion measurements.

Soil and Water Conservation Practices: Designing catchment size for farm ponds under low runoff conditions: Efficient use of stored water.

Groundwater Exploration: Fluctuation of groundwater levels in low runoff area: Exploring ways of collecting more runoff to recharge soil Profile.

4.4 Model : Silvi-horti pasture in Arid to semi-arid *kharif* alfisols in Chalka Region

Region : Karnataka Plateau (Rayalseema as inclusion), hot arid with deep loamy and clayey mixed red and black soils, low to medium AWC and LGP 60 – 90 days. (AESR 3.0)

Target Districts:

First Priority: Anantapur
Second Priority: -
Selected districts: -

Farming system model:

Crop Production System: Groundnut, Pigeon pea, Sorghum, Sunflower

Boundary Plantation: *Tamarindus indica*, Pongamia, *Eucalyptus camaldulensis, Prosopis juliflora*

Live fence

Outer Layer: Cactus, Lawsonia
Inner Layer: *Muraya coenigi, Carissa carundus*

Trees on crop lands

Fodder/green biomass: *Acacia nilotica, Ailanthus excelsa, Albizzia lebbeck, Hardwickia binata, Dalbergia sissoo, Azadirachta indica*
Fruit: Custard apple, Pomegranate,Tamarind, Fig, Jamun, Mango
Wood (Commercial/Farm Use/Fuel Wood): *Acacia nilotica, Acacia auriculiformis, Dalbergia sissoo*

Medicinal & Aromatic Plants: *Cassia angustifolia, Catharanthu roseus*, Palma rosa

Vegetables: Cluster bean, Pumpkin, Cow pea, Round melon, Drum stick

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Sheep, Goat, Poultry

Water harvesting techniques: Manage in <10 ha watersheds: Soil water balance studies: Runoff-erosion measurements: More emphasis on *in situ* water conservation: Increasing soil infiltration capacity and reducing soil crusting problem: Land shaping to store more water in the soil profile: Inter-plot water harvesting of 1:1 cropped to uncropped land: Dead furrows at 3.6 m intervals: Absorption/drainage type terraces: Vegetative barriers: Gully control.

Soil and Water Conservation Practices: Increasing catchment area: Designing catchment size for farm ponds under low runoff conditions: Water harvesting in lined dug-out ponds and use for life-saving irrigation: Efficient use of stored water

Groundwater Exploration: Fluctuation of groundwater levels in low runoff area: Exploring ways of collecting more runoff to recharge soil profile.

4.5 Model : Agri-silvi-horticulture in Semi-arid – *kharif* and *rabi* vertisols

Region : Karnataka Plateau (Rayalseema as inclusion), hot arid with deep loamy and clayey mixed red and black soils, low to medium AWC and LGP 60 – 90 days. (AESR 3.0)

Target districts:

First Priority: -
Second Priority: Bellary
Selected districts: -

Farming system model:

Crop Production System: Sorghum, Sunflower, Cotton

Boundary Plantation: *Azadirachta indica*, *Eucalyptus camaldulensis, Acacia nilotica*

Live fence

Outer Layer: Cactus, Eucalyptus, Agave

Inner Layer: Gliricidia, *Tectona grandis, Muraya coenigi.*

Trees on crop lands

Fodder/green biomass: *Hardwickia binata, Albizzia lebbeck, Leucaena leucocephala, Dalbergia sissoo, Azadirachta indica.*

Fruit: Mango, Sapota, Pomegranate, Fig, Guava

Wood (Commercial/Farm Use/Fuel Wood): *Tectona grandis, Acacia auriculiformis, Acacia nilotica*

Medicinal & Aromatic Plants: *Vetiveria zyzanoides*, Palmarosa, *Cassia angustifolia, Catharanthus roseus*

Vegetables: Tomato, Chillies, Brinjal, Amaranth, Bitter gourd

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Goat, Sheep, Poultry

Water harvesting techniques: Runoff harvesting in ponds for supplementary irrigation: Design of pond size for catchment size: Efficient use of harvested water: Economic benefits of farm ponds.

Soil and Water Conservation Practices: Manage in 10-100 ha watersheds: Land configuration system: Absorption/Drainage type terraces: Vegetative barriers: Compartmental bunds for raising crops on conserved soil moisture: Land surface treatment to increase soil water profile storage: Sowing across the slope and ridging later: Contour farming: (cultivation and sowing along contour): Graded border strips: Runoff rainfall model: Erosion versus productivity of soils

Groundwater Exploration: Feasibility studies on recharging of groundwater: Fluctuation of groundwater levels: Design of percolation tanks for recharging groundwater: Limitation on use of groundwater for irrigation.

4.6 Model : Agri-horti-silviculture in Semi-arid – *kharif* and *rabi* vertisols

Region : Karnataka Plateau (Rayalseema as inclusion), hot arid with deep loamy and clayey mixed red and black soils, low to medium AWC and LGP 60 – 90 days. (AESR 3.0)

Target Districts:

First Priority: Bijapur
Second Priority: -
Selected districts: Raichur

Farming system model:

Crop Production System: Sorghum, Pearl millet, Sunflower

Boundary Plantation: *Eucalyptus camaldulensis, Tectona grandis*

Live fence

Outer Layer: *Agave sisalana*, Cactus

Inner Layer: *Leucaena leucocephala, Carrissa carundus, Sesbania, Muraya coenigi*

Trees on crop lands

Fodder/green biomass: *Dalbergia sissoo, Glyricidia, Albizzia lebbeck, Hardwickia binata, Cassia siamia, Azadirachta indica*

Fruit: Mango, Pomegranate, Sapota, Ber, Jamun, Tamarind.

Wood (Commercial/Farm Use/Fuel Wood): *Eucalyptus hybrid, Acacia auriculiformis, Acacia nilotica*

Medicinal & Aromatic Plants: *Cassia angustifolia, Catharanthus roseus*, Palma rosa, *Vetiveria zyzanoides*, Rose Geranium,

Vegetables: Onion, Brinjal, chillies, Cowpea, Cucumber, Cluster bean, Drumstick

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Goat, Sheep, Poultry

Water harvesting techniques: Runoff harvesting in ponds for supplementary: Irrigation: Design of pond size for catchment size: Efficient use of harvested water: Economic benefits of farm ponds.

Soil and Water Conservation Practices: Manage in 10-100 ha watersheds:Land configuration system: Absorption/Drainage type terraces: Vegetative barriers: Compartmental bunds for raising crops on conserved soil moisture: Land surface treatment to increase soil water profile storage: Sowing across the slope and ridging later: Contour farming (cultivation and sowing along contour:Graded border strips: Runoff rainfall model: Erosion versus productivity of soils.

Groundwater Exploration: Feasibility studies on recharging of groundwater,:Fluctuation of groundwater levels: Design of percolation tanks for recharging groundwater: Limitation on use of groundwater for irrigation.

4.7 Model : Agri-horti-silviculture in Sub-humid *kharif* and *rabi* inceptisols

Region : Northern plain (And Central Highlands) including Aravallis, hot semi-arid eco-region: North Punjab Plain, Ganga-Yamuna Doab and Rajasthan Upland, hot semi-arid with deep loamy alluvium-derived soils (occasional saline and sodic phases), medium AWC and LGP 90-120 days. (AESR 4.1)

Target Districts:

First Priority: -
Second Priority: Jaipur, Sawai madhopur
Selected districts: Agra, Mathura

Farming system model:

Crop Production System: Pearl millet, Rape seed Mustard, Fruit & Vegetables

Boundary Plantation: *Azadirachta indica, Albizzia lebbeck,* Pongamia, *Prosopis*

Live fence

Outer Layer: *Agave sisalana,*

Inner Layer: *Lawsonia alba*, Agave, *Carissa carundus*

Trees on crop lands

Fodder/green biomass: *Azadirachta indica, Leucaena leucocephala*, *Albizzia lebbeck*, *Hardwickia binata*, Pongamia, *Cassia siamea*, Bauhinia

Fruit: Mango, gauva, Amla, Phalsa, Jamun, Caronda

Wood (Commercial/Farm Use/Fuel Wood): Eugenia, Eucalyptus, *Acacia nilotica*

Medicinal & Aromatic Plants: *Papaver somniferum*, Palma rosa, *Cymbopogan flexuosus*, *Vetiveria zyzanoides*

Vegetables: Tomato, Chillies, Brinjal, Okra , Bottle gourd, Amaranth, Cow pea.

Livestock Production System: Female Cattle, Female Buffaloes, Goat, Poultry

Water harvesting techniques: Runoff harvesting in ponds for supplementary irrigation: Design of pond size for catchment size: Efficient use of harvested water:Economic benefits of farm ponds.

Soil and Water Conservation Practices: Manage in 10-100 ha watersheds: Land surface treatment to increase soil water profile storage: Sowing across the slope and ridging later: Compartmental bunds for raising crops on conserved soil moisture: Contour farming: Graded border strips: Soil conservation: Leveling of humps: Gully beds and sides: Bench terracing on gully sides: Widening of gully beds: Earthen/masonry check dams: Runoff rainfall model Erosion vs productivity of soils,.

Groundwater Exploration: Fluctuation of groundwater levels: Design of percolation tanks for recharging groundwater: Feasibility studies on recharging of groundwater: Limitation on use of groundwater for irrigation

4.8 Model : Tree farming/ Silvi pasture in Marginal and semi *kharif* ard ustalf - vertisols in West Alluvial plain region

Region : Northern Plain (and Central highlands) including aravallis north Gujarath Plain and east Rajasthan uplands, hot dry semi-arid with deep loamy grey brown and alluvium derived soils, medium AWC, LGP 90-120 days (AESR 4.2)

Target Districts:

First Priority: -
Second Priority: Sabarkanta
Selected districts: Mehasana

Farming system model:

Crop Production System: Pearl millet, Sorghum, Maize, Castor

Boundary Plantation: *Azadirachta indica, Acacia tortiles, Dalbergia sissoo,*

Live fence

Outer Layer: Agave, Cactus, *Parkinsonia aculeata*

Inner Layer: *Tecomella undulata, Azadirachta indica,* Eucalyptus, *Carissa carundus.*

Trees on crop lands

Fodder/green biomass: *Albizzia lebbeck, Azadirachta indica, Acacia Ibida, Cassia siamia, Dalbergia sissoo, Hardwickia binata, Acacia nilotica*

Fruit: Mango, Pome granate, Guava, Ber, Fig, Jamun

Wood (Commercial/Farm Use/Fuel Wood): *Acacia tortiles*, Eucalyptus

Medicinal & Aromatic Plants: *Plantago ovata, Cassia angustifolia,* Liquorice

Vegetables: Drum stick, Cluster bean, Cow pea, Long melon, Okra.

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Goats

Water harvesting techniques: Manage in<10ha watersheds: More emphasis on *in situ* water conservation: Increasing soil infiltration capacity and reducing soil crusting problem: Contour furrowing: Absorption terracing: Contour trences: Land Surface treatment to increase soil water profile storage: Inter-row water harvesting: Inter-plot water harvesting of 1:1 cropped to uncropped land: Dead furrows at 3.6 m intervals: Gully control: Soil water balance studies: Runoff-erosion measurements.

Soil and Water Conservation Practices: Increasing catchment area: Designing catchment size for farm ponds under low runoff conditions: Water use for life-saving irrigation: Efficient use of stored water.

Groundwater Exploration: Fluctuation of groundwater levels in low runoff area: Exploring ways of collecting more runoff to recharge soil profile.

4.9 Model : Horti-silvipasture in Semi-arid – *kharif* and *rabi* vertisols

Region : Northern plain (And Central highlands) including Aravallis, hot semi-arid eco-region: North Gujrat Plain (inclusion of Aravalli range and east Rajasthan Uplands), hot dry semi-arid Eco Sub Region with deep loamy Grey Brown and alluvium-derived soils, medium AWC and LGP 90-120 days (AESR 4.2)

Target Districts:

First Priority: Udaipur
Second Priority: Bhilwara
Selected districts: Dungarpur

Farming system model:

Crop Production System: Maize, Sorghum, Sesame

Boundary Plantation: *Prosopis cineraria, Acacia tortiles, Hardwickia binata, Lawsonia alba*

Live fence

Outer Layer: *Parkinsonia aculeata*, Agave, Cactus, *Lawsonia alba*
Inner Layer: *Carissa carundus, Prosopis cineraria, Acacia senegal, Lawsonia alba*

Trees on crop lands

Fodder/green biomass: *Hardwickia binata, Albizzia lebbeck, Dalbergia sissoo, Azadirachta indica, Prosopis cineraria, Dichrostachys. Acacia nilotica*
Fruit: Ber, Date palm, Jamun, Fig, Phalsa, Karonda
Wood (Commercial/Farm Use/Fuel Wood): *Dalbergia sissoo, Acacia tortiles*

Medicinal & Aromatic Plants: *Plantago ovata, Cassia angustifolia*, Safed musli, *Papaver somniferum*

Vegetables: Clusterbean, Cowpea, Amaranth, Round melon, Long melon

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Sheep, Goats

Water harvesting techniques: Manage in<10ha watersheds: More emphasis on *in situ* water Conservation: Increasing soil infiltration capacity and reducing soil crusting problem: Contour furrowing: Absorption terracing: Contour trences: Land Surface treatment to increase soil water profile storage: Inter-row water harvesting: Inter-plot water harvesting of 1:1 cropped to uncropped land: Dead furrows at 3.6 m intervals: Gully control: Soil water balance studies: Runoff-erosion measurements.

Soil and Water Conservation Practices: Increasing catchment area: Designing catchment size for farm ponds under low runoff conditions: Water use for life-saving irrigation: Efficient use of stored water.

Groundwater Exploration: Fluctuation of groundwater levels in low runoff area: Exploring ways of collecting more runoff to recharge soil profile.

4.10 Model : Agri-silvi-horticuture in Sub-humid *kharif* and *rabi* inceptisols in Indo-Gangetic Plain Region

Region : Northern Plain (and central highlands), Ganga Yamuna doab, Rohil Khand and Awadh plain hot moist semi-arid with deep loamy alluvium derived soils medium to high AWC and LGP: 120-150 days (AESR.4.3)

Target Districts:

First Priority: -

Second Priority: -

Selected districts: Kanpur

Farming system model:

Crop Production System: Pigeonpea, Chickpea, Rice, Maize, Sorghum

Boundary Plantation: *Dalbergia sissoo*, Eucalyptus, *Acacia nilotica*

Live fence

Outer Layer: *Lawsonia inermis*, *Agave sisalana*

Inner Layer: *Carissa carandus*, Leucaena, Sesbania, Moringa

Trees on crop lands

Fodder/green biomass: *Luecaena leucocephala, Azadirachta indica, Albizia lebbeck, Bauhinia purpurea, A. procera, Butea monosperma, Albizia amara, Dalbergia sissoo*

Fruit: Amla, Guava, Ber, Mango Bael, Jamun

Wood (Commercial/Farm Use/Fuel Wood): *Dendrocalamus*, Eucalyptus, *Tectona grandis*

Medicinal & Aromatic Plants: *Cymbopogan flexuosus, Papaver somniferum,* Palmarosa, *Vetiveria zyzanoides*

Vegetables: Brinjal, Chillies, Cluster bean, Cow pea, Round melon, Okra

Water harvesting techniques: Manage in 100-1000 ha watersheds: Large scale soil and water conservation practices: Contour farming: Inter-plot water harvesting: Raised bed and sunken System: Provision for drainage: Design of Structures: Drainage terraces on slope 2-6%: Graded trenches (16-33%): Terraces with dry rubble gravel or lateritic pitched wall: Streambank protection: Flood mitigation: Surface and subsurface drainage: Erosion Versus Productivity.

Soil and Water Conservation Practices: Design of small dams: Efficient use of irrigation water for winter crop.

Groundwater Exploration: Groundwater recharge systems from percolation tanks:Efficient use of groundwater for sustained purposes

4.11 Model : Agri-horti-silvi culture in Arid to semi-arid vertic inceptisol-vertisols

Region : Northern plain (and Central highlands) including Aravallis, hot semi-arid eco-region: Madhya Bharat plateu and Bundelkhand uplands, hot, moist semi-arid Eco Sub-Region with deep loamy and clayey mixed Red and Black soils, medium to high AWC and LGP 120-150 days(AESR 4.4)

Target Districts:

First Priority: -
Second Priority: -
Selected districts: Hamirpur, Jalun, Jhansi

Farming system model:

Crop Production System: Chickpea, Lentil, Sorghum, Wheat

Boundary Plantation: *Dalbergia sissoo, Lawsonia inermis, Acacia nilotica*

Live fence

Outer Layer: *Lawsonia inermis*, Cactus, *Agave sisalana*
Inner Layer: *Carissa carandus, Leucaena leucocephala, Emblica officinalis.*

Trees on crop lands

Fodder/green biomass: *Leucaena leucocephala*, *Melia azadirach, Dichro stachys cineraria, Albizzia amara, Albizzia lebbeck, Hardwickia binata, Acacia nilotic*a
Fruit: *Emblica officinalis* {amla], Guava, Ber, Mango
Wood (Commercial/Farm Use/Fuel Wood): *Acacia tortiles, Acacia senegal,* Eucalyptus sps.

Medicinal & Aromatic Plants: *Rauvolfia serpentina, Vetivera zyzanoides*, Palmarosa, Safed musli, Asgand.

Vegetables: Bottle gourd, Brinjal, Tomato, Chillies, Brinjal, Cowpea, Okra.

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Goat, Poultry

Water harvesting techniques: Runoff harvesting in ponds for supplementary irrigation: Design of pond size for catchment size: Efficient use of harvested water: Economic benefits of farm ponds.

Soil and Water Conservation Practices: Manage in 10-100 ha watersheds: Land surface treatment to increase soil water profile storage: Sowing across the slope and ridging later: Compartmental bunds for raising crops on conserved soil moisture: Contour farming: Graded border strips: Soil conservation: Leveling of humps: Gully beds and sides: Bench terracing on gully sides: Widening of gully beds: Earthen/masonry check dams: Runoff rainfall Model: Erosion vs productivity of soils.

Groundwater Exploration: Fluctuation of groundwater levels: Design of percolation tanks for recharging groundwater: Feasibility studies on recharging of groundwater: Limitation on use of groundwater for irrigation.

4.12 Model : Agri-horti silvi culture for semi-arid regions

Region : Central highlands (malwa), Gujarath Plain and Kathiawar Peninsula semi-arid eco region with shallow and medium loamy to clayey black soils, medium AWC and LGP 90-120 days. (AESR 5.1)

Target Districts:

First Priority: -

Second Priority: Amreli

Selected districts: - Bhavnagar, Junagarh

Farming system model:

Crop Production System: Groundnut, Pearl millet, Sorghum

Boundary Plantation: *Prosopis cineraria, Acacia nilotica,* Lawsonia

Live fence

Outer Layer: Opuntia sps., *Lawsonia alba, Ziziphus mauritiana*

Inner Layer: *Prosopis cineraria, Pithecalobium dulce, Parkinsonia aculeate*

Trees on crop lands

Fodder/green biomass: *Dichrostachys cineraria, Albizia lebbeck, Leucaena leucocephala, Gliricidia, Pongamia pinnata*

Fruit: Custard apple Mango, Pomegranate Phalsa, Fig, Jamun, Tamarind

Wood (Commercial/Farm Use/Fuel Wood): *Hardwickia binata, Acacia nilotica, Eucalyptus* .

Medicinal & Aromatic Plants: *Plantago ovata, Cassia angustifolia*, Liquorice.

Vegetables: Cowpea, Cluster bean, Brinjal, Okra, Long melon, Drum stick.

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Sheep, Goat

Water harvesting techniques: Increasing soil infiltration capacity and reducing soil crusting problem: Land Surface treatment to increase soil water profile storage: System of land shaping into compartments to store more water in the soil profile: Inter-plot water harvesting of 1:1 cropped to uncropped land: Dead furrows at 3.6 m intervals: Dune stabilization: Sub-surface moisture conservation: Soil water balance studies: Runoff-erosion measurements.

Soil and Water Conservation Practices: Designing catchment size for farm ponds under low runoff conditions: Efficient use of stored water.

Groundwater Exploration: Fluctuation of groundwater levels in low runoff area: Exploring ways of collecting more runoff to recharge soil Profile.

4.13 Model : Agri-horti-silviculture in Semi-arid – *kharif* and *rabi* vertisols in Southern Malwa Region

Region : Central highlands (Malwa), Gujarat plain and Kathiawar Peninsula, semi-arid eco-region: Madhya Bharat Plateau, Western Malwa Plateau, Eastern Gujrat Plain, Vindhyan and Satpura range, Narmada valley hot moist semi-arid with medium and deep, clayey black soils (shallow Black soils as inclusions), medium to high AWC and LGP 120-150 days. (AESR 5.2)

Target Districts:

First Priority: -
Second Priority: -
Selected districts: Indore, Dhar, Ujjain, Dewas

Farming system model:

Crop Production System: Soybean, Sorghum, Chickpea, Maize

Boundary Plantation: *Acacia nilotica, Dalbergia sissoo*, Eucalyptus, *Cieba pentandra*

Live fence

Outer Layer: Cactus, Lawsonia
Inner Layer: *Carissa carundus,* Gliricidia , Sesbania, Luecaena

Trees on crop lands

Fodder/green biomass: *Dichrostachys cineria, Albizia amara, Faidherbia albida, Hardwickia binata, Cassia siamea*, *Leucaena leucocephala, Albizia lebbeck*
Fruit: Ber, Pomegranate, Mango, Fig, Tamarind
Wood (Commercial/Farm Use/Fuel Wood): *Tectona grandis*, Eucalyptus

Medicinal & Aromatic Plants: *Withamnia somnifera, Rauvolfia serpentina, Vetiver zyzanoides,* Palma rosa, Liquorice.

Vegetables: Chillies, Okra, Watermelon, Cowpea, Cluster bean, Amaranth, Round melon.

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Goat, Poultry

Water harvesting techniques: Runoff harvesting in ponds for supplementary irrigation: Design of pond size for catchment size: Efficient use of harvested water: Economic benefits of farm ponds

Soil and Water Conservation Practices: Manage in 10-100 ha watersheds: Land surface treatment to increase soil water profile storage: Sowing across the slope and ridging later: Contour farming: Graded border strips: Land configuration system: Compartmental bunds for raising crops on conserved soil moisture: Surface drainage: Mulching: Vegetative barriers: Runoff rainfall model Erosion versus productivity of soils.

Groundwater Exploration: Feasibility studies on recharging of groundwater: Fluctuation of groundwater levels: Design of percolation tanks for recharging groundwater: Limitation on use of groundwater for irrigation.

4.14 Model : Tree farming/Silvi pasture in Marginal and semi *kharif* arid ustalf - vertisols in West Alluvial plain region

Region : Central highlands (Malwa), Gujarat plain and Kathiawar peninsula, semi-arid eco-region: Madhya Bharat Plateau, Western Malwa Plateau, Eastern Gujrat Plain, Vindhyan and Satpura range, Narmada valley hot moist semi-arid with medium and deep, clayey black soils (shallow Black soils as inclusions), medium to high AWC and LGP 120-150 days Panchamahal. (AESR 5.2)

Target Districts:

First Priority: -

Second Priority: Panchamahal, Surat, Baroda, Bharuch, Mandsaur

Selected districts: -

Farming system model:

Crop Production System: Pearl millet, Sorghum, Maize, Castor

Boundary Plantation: Eucalyptus, *Acacia tortiles*

Live fence

Outer Layer: Agave, Cactus

Inner Layer: Leucaena, Gliricidia, *Prosopis cineraria*

Trees on crop lands

Fodder/green biomass: *Albizzia lebbeck, Melea azadirach, Azadirachta indica, Faitherbia albida, Hardwickia binata, Cassia siamea, Ailanthus excelsa.*

Fruit: Mango, custard apple, Ber, Jamun, Fig , Pome granate

Wood (Commercial/Farm Use/Fuel Wood): *E.tereticornis, A.cupressiformis, A.auriculiformis*

Medicinal & Aromatic Plants: *Plantago ovata, Cassia angustifolia*, Safed musli

Vegetables: Cow pea, Drum stick, Round melon,, long melon, cluster bean

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Goats

Water harvesting techniques: Manage in<10ha watersheds: More emphasis on *in situ* water conservation: Increasing soil infiltration capacity and reducing soil crusting problem : Contour furrowing: Absorption terracing: Land Surface treatment to increase soil water profile storage: Inter-row water harvesting: Inter-plot water harvesting of 1:1 cropped to uncropped land: Dead furrows at 3.6 m intervals: Gully control: Soil water balance studies: Runoff-erosion measurements: Contour trences.

Soil and Water Conservation Practices: Increasing catchment area: Designing catchment size for farm ponds under low runoff conditions: Water use for life-saving irrigation: Efficient use of stored water.

Groundwater Exploration: Fluctuation of groundwater levels in low runoff area: Exploring ways of collecting more runoff to recharge soil profile.

4.15 Model : Agri-horti-silviculture in Semi-arid – *kharif* and *rabi* vertisols in Plateau Region

Region : Deccan Plateau, hot semi-arid eco-region: South Western Maharashtra and North Karnataka Plateau, hot dry semi-arid Eco Sub Region with shallow and medium loamy black soils (deep clayey black soils as inclusion), medium to high AWC and LGP 90- 120 days (AESR 6.1)

Target Districts:

First Priority: Solapur
Second Priority: Beed
Selected districts: Osmanabad

Farming system model:

Crop Production System: Sorghum, Pearl millet, Sunflower

Boundary Plantation: *E.camaldulensis, E.hybrid, D.sissoo*

Live fence

Outer Layer: Agave

Inner Layer: *Sesbania grandiflora, L. leucocephala, M. azadirach,* Casuarina

Trees on crop lands

Fodder/green biomass: *D.sissoo, M.azadirach, A.lebbeck, Anogeissus latifolia,* Sesbania, *A. excelsa, C.siamea*

Fruit: Pome granate, Mango, Sapota, Custard apple, Fig, Jamun

Wood (Commercial/Farm Use/Fuel Wood): *E.tereticornis*, Causurina, Leucaena

Medicinal & Aromatic Plants: *Catharanthus roseus*, Palma rosa, *Vetiveria zyzanoides*, Rose Geranium

Vegetables: Onion, Tomato, Okra, Cow pea, Cluster bean, Drumstick

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Goat, Sheep, Poultry

Water harvesting techniques: Runoff harvesting in ponds for supplementary Irrigation: Design of pond size for catchment size: Efficient use of harvested water: Economic benefits of farm ponds.

Soil and Water Conservation Practices: Manage in 10-100 ha watersheds: Land configuration system: Absorption/Drainage type terraces: Vegetative barriers: Compartmental bunds for raising crops on conserved soil: moisture: Land surface treatment to increase soil water profile storage:Sowing across the slope and ridging later: Contour farming (cultivation and sowing: long contour:Graded border strips: Runoff rainfall model: Erosion versus productivity of soils.

Groundwater Exploration: Feasibility studies on recharging of groundwater: Fluctuation of groundwater levels: Design of percolation tanks for recharging groundwater: Limitation on use of groundwater for irrigation.

Model 4.16 : Agri-horti-silviculture in Semi-arid – *kharif* and *rabi* vertisols in Plateau Region

Region : Deccan Plateau, hot semi-arid eco-region: Central and Western maharashtra Plateau and north Karnataka Plateau and north-western Telagana Plateau, hot moist semi-arid, shallow and medium loamy to clayey black soils medium to high AWC and LGP 120-150 days (AESR 6.2)

Target Districts:

First Priority: - Nasik, Adilabad
Second Priority: Jalna, Nizamabad, Parbhani, Nanded
Selected districts: -

Farming system model:

Crop Production System: Sorghum, Pearl millet, Sunflower

Boundary Plantation: *Tectona grandis, Gmelina arborea, E.camaldulensis, E.hybrid*

Live fence

Outer Layer: Agave, Cactus, *Casuarina*
Inner Layer: *Sesbania grandiflora, L. leucocephala, M. azadirach*

Trees on crop lands

Fodder/green biomass: *Albizzia lebbeck, Hardwickia binata, Dalbergia sissoo, Melia azadirach, Anogeissus latifolia,* Sesbania, *Cassia siamea*

Fruit: Mango, Sapota, Custard apple, Ber, Jamun

Wood (Commercial/Farm Use/Fuel Wood): *Acacia nilotica*, *E.tereticornis*, Causurina, Leucaena, *Gmelina arborea*

Medicinal & Aromatic Plants: *Catharanthus roseus*, Palma rosa, *Vetiveria zyzanoides*, Rose Geranium

Vegetables: Onion, Tomato, Okra, Cowpea, Cluster bean, Drumstick

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Goat, Sheep, Poultry

Water harvesting techniques: Runoff harvesting in ponds for supplementary Irrigation: Design of pond size for catchment size: Efficient use of harvested water: Economic benefits of farm ponds.

Soil and Water Conservation Practices: Manage in 10-100 ha watersheds: Land configuration system: Absorption/Drainage type terraces: Vegetative barriers: Compartmental bunds for raising crops on conserved soil: moisture: Land surface treatment to increase soil water profile storage:Sowing across the slope and ridging later: Contour farming (cultivation and sowing: long contour:Graded border strips: Runoff rainfall model: Erosion versus productivity of soils.

Groundwater Exploration: Feasibility studies on recharging of groundwater: Fluctuation of groundwater levels: Design of percolation tanks for recharging groundwater: Limitation on use of groundwater for irrigation.

4.17 Model : Agri-horti-silviculture in Semi-arid – *kharif* and *rabi* vertisols in Plateau Region

Region : Deccan plateau, hot semi-arid eco-region : Eastern Maharashtra Plateau, hot moist semi-arid Eco Sub Region with medium and deep clayey black soils (shallow loamy, to clayey black soils as inclusion), medium to high AWC and LGP 120-150 days (AESR 6.3)

Target Districts:

First Priority: Yeotmal
Second Priority: Akola, Amaravathi, Buldhana
Selected districts: -

Farming system model:

Crop Production System: Cotton, Sorghum, Green gram

Boundary Plantation: *Tectona grandis, Gmelina arborea*, Eucalyptus

Live fence

Outer Layer: *Prosopis Juliflora, Lawsonia alba, Agave sisalana*
Inner Layer: *Carissa carundus*, Leucaena, *Madhuca latifolia, Tectona grandis,* Sesbania, Gliricidia

Trees on crop lands

Fodder/green biomass: *Leucaena leucocephala, Albizzia lebbeck, D.sissoo, A.indica, A.procera*, Gliricidia
Fruit: Pomegranate Ber, Mango, Sapota, Guava, Tamarind
Wood (Commercial/Farm Use/Fuel Wood): *A.nilotica*, Eucalyptus, *Dendrocalamas*.

Medicinal & Aromatic Plants: *Solanum viarum, Catharanthus roseus*, Palmrosa, *Vetiveria zyzanoides, Ocimum viride*

Vegetables: Onion, Chilli, Brinjal, Okra, Amaranth, Bottle gourd.

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Goat, Poultry

Water harvesting techniques: Runoff harvesting in ponds for supplementary Irrigation: Design of pond size for catchment size: Efficient use of harvested water: Economic benefits of farm ponds.

Soil and Water Conservation Practices: Manage in 10-100 ha watersheds: Land configuration system: Absorption/Drainage type terraces: Vegetative barriers: Compartmental bunds for raising crops on conserved soil moisture: Land surface treatment to increase soil water profile storage: Sowing across the slope and ridging later:Contour farming cultivation and sowing along contour: Graded border strips: Runoff rainfall model: Erosion versus productivity of soils.

Groundwater Exploration: Feasibility studies on recharging of groundwater: Fluctuation of groundwater levels: Design of percolation tanks for recharging groundwater: Limitation on use of groundwater for irrigation.

4.18 Model : Agri-horti-silviculture in Semi-arid – *kharif* and *rabi* vertisols

Region : Deccan plateau, hot semi-arid eco-region moderately to gently sloping north sahyadris and western Karnataka Plateau, hot dry sub-humid, shallow and medium loamy and clayey black soils medium to high AWC and LGP 150-180 days. (AESR 6.4)

Target Districts:

First Priority: - Pune

Second Priority: Dharwad, Belgaum, Kolhapur

Selected districts: -

Farming system model:

Crop Production System: Cotton

Boundary Plantation: *Tectona grandis,* Eucalyptus, Casuarina

Live fence

Outer Layer: *Tectona grandis, Eucalyptus*

Inner Layer: Leucaena, Sesbania, Gliricidia

Trees on crop lands

Fodder/green biomass: *Leucaena leucocephala, Azadirachta indica, Albizia lebbeck, D.sissoo, Acacia nilotica*

Fruit: Mango, Sapota, Papaya, Tamarind, Jamun

Wood (Commercial/Farm Use/Fuel Wood): *Leucaena leucocephala , Tectona grandis ,* Eucalyptus, *Dendrocalamas*, *Acacia mangium*

Medicinal & Aromatic Plants: *Solanum viarum, Catharanthus roseus*, Cassia anguistifolia, *Diascorea*

Vegetables: Brinjal, Okra, Amaranth, Tomatto, Chillies

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes

Water harvesting techniques: Runoff harvesting in ponds for supplementary irrigation: Design of pond size for catchment size: Efficient use of harvested water: Economic benefits of farm ponds.

Soil and Water Conservation Practices: Manage in 10-100 ha watersheds: Land configuration system: Absorption/Drainage type terraces: Vegetative barriers: Compartmental bunds for raising crops on conserved soil moisture: Land surface treatment to increase soil water profile storage: Sowing across the slope and ridging later: Contour farming: (cultivation and sowing along contour): Graded border strips: Runoff rainfall model: Erosion versus productivity of soils

Groundwater Exploration: Feasibility studies on recharging of groundwater: Fluctuation of groundwater levels: Design of percolation tanks for recharging groundwater: Limitation on use of groundwater for irrigation

4.19 Model : Agri-horti-silvi culture in Arid to semi-arid *kharif* alfisols in Chalka Region

Region : Deccan plateau (Telangana) and Eastern Ghats, hot semi-arid eco-region : North Telangana plateau, hot moist semi arid with deep loamy and clayey mixed Red and Black soils, medium to very high AWC and LGP 120-150 days (AESR 7.2)

Target districts:

First Priority: Mahaboobnagar
Second Priority: -
Selected districts: Kurnool

Farming system model:

Crop Production System: Groundnut, Pigeon pea, Sorghum, Sunflower

Boundary Plantation: Gliricidia, *Dalbergia sissoo, Eucalyptus hybrid*

Live fence

Outer Layer: Cactus sps., Opuntia sps., *Lawsonia alba*
Inner Layer: Gliricidia, Leucaena, *Muraya coenigi.*

Trees on crop lands

Fodder/green biomass: *Leucaena leucocephala, Gliricidia, Azadirachta indica, Albizia lebbeck, Albizia amara, Faidherbia albida, Hardwickia binata*

Fruit: Custard apple, Ber, Cherimoya, Mango, Tamarind, Jamun

Wood (Commercial/Farm Use/Fuel Wood): *A.nilotica, A. cupressiformis, H.binata, Dalbergia sissoo.*

Medicinal & Aromatic Plants: *Plantago ovata, Cassia angustifolia*, Palmarosa,*Vetiveria zyzanoides*

Vegetables: Cow pea, Clusterbean, Drumstick, Coccinia, Pumpkin, Round melon.

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Sheep, Goat, poultry

Water harvesting techniques: Manage in <10 ha watersheds: Soil water balance studies: Runoff-erosion measurements: More emphasis on *in situ* water conservation: Increasing soil infiltration capacity and reducing soil crusting problem: Land shaping to store more water in the soil profile:Inter-plot water harvesting of 1:1 cropped to uncropped land: Dead furrows at 3.6 m intervals: Absorption/drainage type terraces: Vegetative Barriers: Gully control.

Soil and Water Conservation Practices: Increasing catchment area: Designing catchment size for farm ponds under low runoff conditions: Water harvesting in lined dug-out ponds and use for life-saving irrigation: Efficient use of stored water: Groundwater Exploration: Fluctuation of groundwater levels in low runoff area: Exploring ways of collecting more runoff to recharge soil profile.

4.20 Model : Agri-horti- silvi culture in Arid to semi-arid *kharif* alfisols in Chalka Region

Region : North Telangana Plateau. Hot moist semi-arid ESR with deep loamy and clayey mixed red and black soils, medium to very high AWC and LGP: 120-150 days. (AESR 7.2)

Target Districts:

First Priority: -
Second Priority: Nalgonda, Medak
Selected districts: -

Farming system model:

Crop Production System: Castor, Groundnut, Sorghum, Pigeonpea, Greengram, Cotton

Boundary Plantation: Eucalyptus, *A.nilotica, A. tortiles*

Live fence

Outer Layer: *Agave sisalana,* Cactus
Inner Layer: Gliricidia, Sesbania, Leucaena, Custard apple, Guava. *Muraya coenigi*

Trees on crop lands

Fodder/green biomass: *Albizzia lebbeck, D.sissoo*, Leucaena, *Azadiracta, Hardwickia binata, Acacia albida*
Fruit: Custard apple, Tamarind, Jamun, Mango, Ber
Wood (Commercial/Farm Use/Fuel Wood): *Dalbergia sissoo, A. auriculiformis, A.nilotica, Hardwickia binata*

Medicinal & Aromatic Plants: *Cassia angustifolia, Catharanthus roseus, Plantago ovata,* Palmarosa, *Vetiveria zyzanoides*.

Vegetables: Cluster bean, Drum stick, Cucumber, Cow pea, Ridge gourd, Round melon, Okra, Water melon.

Livestock Production System: Sheep, Goat, Male & Female Cattle

Water harvesting techniques: Manage in <10 ha watersheds: Soil water balance studies: Runoff-erosion measurements: More emphasis on *in situ* water conservation: Increasing soil infiltration capacity and reducing soil crusting problem: Land shaping to store more water in the soil profile: Inter-plot water harvesting of 1:1 cropped to uncropped land: Dead furrows at 3.6 m intervals: Absorption/drainage type terraces: Vegetative barriers: Gully control.

Soil and Water Conservation Practices: Increasing catchment area: Designing catchment size for farm ponds under low runoff conditions: Water harvesting in lined dug-out ponds and use for life-saving irrigation: Efficient use of stored water.

Groundwater Exploration: Fluctuation of groundwater levels in low runoff area: Exploring ways of collecting more runoff to recharge soil profile.

4.21 Model : Agri-horti-silviculture in Semi-arid late *kharif* / *rabi* vertisols in Chalka Region

Region : Eastern ghats and Tamil nadu uplands and Deccan (Karnataka) Plateau, hot semi-arid eco-region: Tamil Nadu Uplands and Leeward flanks of South Sahayadris, hot dry semi-arid Eco Sub Region with moderately deep to deep, loamy to clayey , mixed Red and Blacksoils, medium AWC and LGP 90-120 days (AESR 8.1)

Target Districts:

First Priority: -
Second Priority: Coimbatore
Selected districts: Kamarajar, Tirunalveli

Farming system model:

Crop Production System: Cotton, Black gram, Pearl millet, Groundnut

Boundary Plantation: *Casurina equisetifolia, Eucalyptus camaldulensis, E.tereticornis*

Live fence

Outer Layer: *Prosopis juliflora*
Inner Layer: *Tectona grandis, Sesbania grandiflora,* Causuarina

Trees on crop lands

Fodder/green biomass: *Ailanthas excelsa, Albizzia lebbeck, Leucaena Leuecocephala, Hardwickia binata, A.indica*
Fruit: Mango, Sapota, Fig Jamun, Pomegranate
Wood (Commercial/Farm Use/Fuel Wood): Eucalyptus, *L.leucocephala, A.nilotica,* Casuarina, *A.holosericea*

Medicinal & Aromatic Plants: *Cassia aungstifolia,* Palmarosa, *Vetiveria zyzanoides*, Jasmine, Rose geranium.

Vegetables: Okra, Bittergourd, Ridge gourd, Chilles,Brinjal, Amaranth

Livestock Production System: Sheep, Goat

Water harvesting techniques: Manage in <10 ha watersheds: Soil water balance Studies: Runoff-erosion measurements: More emphasis on *in situ* water conservation: Increasing soil infiltration capacity and reducing soil crusting problem: Land shaping to store more water in the soil profile: Inter-plot water harvesting of 1:1 cropped to uncropped land: Dead furrows at 3.6 m intervals: Absorption/drainage type terraces: Vegetative Barriers: Gully control.

Soil and Water Conservation Practices: Increasing catchment area: Designing catchment size for farm ponds under low runoff conditions: Water harvesting in lined dug-out ponds and use for life-saving irrigation: Efficient use of stored water.

Groundwater Exploration: Fluctuation of groundwater levels in low runoff area: Exploring ways of collecting more runoff to recharge soil Profile.

4.22 Model : Agri-horticulture in Arid to semi-arid *kharif* alfisols in Chalka Region

Region : Eastern ghats and Tamil Nadu uplands and Deccan (Karnataka) Plateau, hot semi-arid eco-region: Central Karnataka Plateau, hot moist semi-arid Eco Sub Region with medium to deep red loamy soils, low AWC and LGP 120-150 days (AESR 8.2)

Target Districts:

First Priority: Chittoor
Second Priority: Dharmapuri, Selam
Selected districts: Bangalore, Mandya, Mysore

Farming system model:

Crop Production System: Finger millet, Horse gram, Sorghum, Fruit & Vegetables

Boundary Plantation: *Tectona grandis, D. sissoo, Tamarindus indica*

Live fence

Outer Layer: Cactus, *Agave sisalana*
Inner Layer: *C.carundus*, Leucaena, Gliricidia, *Sesbania sesban*

Trees on crop lands

Fodder/green biomass: *L.leucocephala, Albizzia lebbeck, Dalbergia sissoo*, *A.indica*, Pongamia, *Cassia siamea*
Fruit: Mango, Pomegranate, Sapota, Guava, Custard apple, Jamun
Wood (Commercial/Farm Use/Fuel Wood): *A.nilotica, A.auriculiformis, Tectona grandis, Santalum album*

Medicinal & Aromatic Plants: *Catharanthus roseus, Cassia angustifolia, Solanum viarum, Dioscorea*, Geranium, Pogostemon patchouli, Jasmine

Vegetables: Tomato, Chillies, Okra Water melon, Bitter gourd, Drum stick, Brinjal, Bitter gourd.

Livestock Production System: Female Cattle, Male Cattle, Female , Buffaloes, Sheep, Goat, Poultry

Water harvesting techniques: Manage in <10 ha watersheds, Soil water balance Studies: Runoff-erosion measurements: More emphasis on *in situ* water conservation: Increasing soil infiltration capacity and reducing soil crusting problem: Land shaping to store more water in the soil profile: Inter-plot water harvesting of 1:1 cropped to uncropped land: Dead furrows at 3.6 m intervals: Absorption/drainage type terraces: Vegetative barriers: Gully control.

Soil and Water Conservation Practices: Increasing catchment area: Designing catchment size for farm ponds under low runoff conditions: Water harvesting in lined dug-out ponds and use for life-saving irrigation: Efficient use of stored water:

Groundwater Exploration: Fluctuation of groundwater levels in low runoff area: Exploring ways of collecting more runoff to recharge soil profile.

4.23 Model : Agri-horti-silviculture in Dry sub-humid sub montane *kharif* and *rabi* incepti/ antisols in Shivalik Region

Region : Northern plain, hot subhumid (dry) eco-region: Punjab and Rohilkhand plains, hot dry/moist sub humid transitional Eco Sub Region with deep, loamy to clayey alluvium derived (inclusion of saline and sodic phases) soils, medium AWC and LGP120-150 days. (AESR 9.1)

Target Districts:

First Priority: -
Second Priority: -
Selected districts: Hoshiarpur, Patiala

Farming system model:

Crop Production System: Maize, Wheat, Fruit and Vegetable

Boundary Plantation: *E.hybrid*, Poplar, Cordia, *Grewia optiva*

Live fence

Outer Layer: Poplar

Inner Layer: Leucaena, *D.sissoo*, Glyricidia.

Trees on crop lands

Fodder/green biomass: *Grewia optiva, D.sissoo* Leucaena, *Butea monosperma, A.lebbeck, Ailanthus excelsa, Bauhinia purpuria, Anogeisus latifolia*

Fruit: Aegle marmalos [bael] , Jamun, Phalsa, Mulberry, Ber.

Wood (Commercial/Farm Use/Fuel Wood): *A.catechu*, Eucalyptus, Poplar, *Leucaena diversifolia*

Medicinal & Aromatic Plants: Spear mint, Japanese mint, Celery, Ocimum viride

Vegetables: Tomato, Chillies, Brinjal, Cow pea, Cluster bean, Long melon, Amaranth

Livestock Production System: Cattle Female, Buffaloes Female, Cattle Male, Goat

Water harvesting techniques: Manage in 10-100 ha watersheds: Design of pond size for catchment size for runoff harvesting in ponds: Efficient use of harvested water for supplementary irrigation: Economic benefits of farm ponds

Soil and Water Conservation Practices: Water harvesting Land surface treatment to increase soil water profile storage: Contour farming (cultivation and sowing along contour): Sowing across the slope and ridging later: Bench terracing: Compartmental bunds: Graded border strips: Runoff rainfall model: Erosion versus productivity of soils: Gully beds and sides:Cover crop management through intercropping.

Groundwater Exploration: Fluctuation of groundwater levels: Feasibility studies on recharging of groundwater: Design of percolation tanks for recharging roundwater: Limitation on use of groundwater for irrigation.

4.24 Model : Agri-horti-silviculture in Sub-humid *kharif* and *rabi* inceptisols in Diara Region

Region : Northern plain, hot sub humid (dry) eco-region : Rohilkhand, Avadh and south Bihar plains, hot dry sub humid with deep loamy alluvium-derived soils medium to high AWC and LGP 150 – 180 days (AESR 9.2)

Target Districts:

First Priority: -
Second Priority: -
Selected districts: Faizabad, Sultanpur, Azamgarh

Farming system model:

Crop Production System: Rice, Pearl millet, Chickpea, Wheat

Boundary Plantation: *Dalbergia sissoo, Acacia nilotica, Tectona grandis, Hardwickia binata, Madhuca latifolia*

Live fence

Outer Layer: Eucalyptus, Poplar
Inner Layer: *Sesbania grandiflora, Leucaena, Carissa carandus, Morus alba.*

Trees on crop lands

Fodder/green biomass: *Leucaena, D. sissoo, Azadiracta indica, Syzygium cumini, Sesbania, Pongamia, Cassia siamea*
Fruit: Mango, Guava, Amla, Ber, Phalsa, Bael, Jamun
Wood (Commercial/Farm Use/Fuel Wood): *Tectona grandis,* Eucalyptus, A.nilotica, Poplar

Medicinal & Aromatic Plants: *Papaver somniferum,* Palmarosa*, Vetiveria zyzanoides, Cymbopogan flexuosus*

Vegetables: Tomato, Brinjal, Okra, Chilli, Amaran-thes

Livestock Production System: Female Cattle, Female Buffaloes, Male Cattle, Sheep, Goat, Poultry

Water harvesting techniques: Runoff harvesting in ponds for supplementary irrigation: Design of pond size for catchment size: Efficient use of harvested water and Economic benefits of farm ponds

Soil and Water Conservation Practices: Manage in 10-100 ha watersheds: Land surface treatment to increase soil water profile storage: Sowing across the slope and ridging later: Compartmental bunds for raising crops on conserved soil moisture: Contour farming: Graded border strips: Soil conservation; Leveling of humps: Gully beds and sides: Bench terracing on gully sides: Widening of gully beds: Earthen/masonry check dams: Runoff rainfall model and Erosion vs productivity of soils

Groundwater Exploration: Fluctuation of groundwater levels: Design of percolation tanks for recharging groundwater: Feasibility studies on recharging of groundwater and Limitation on use of groundwater for irrigation.

4.25 Model : Agri-horti-silviculture in Semi-arid – *kharif* and *rabi* vertisols in Southern Malwa Region

Region : Central highlands (Malwa and Bundekhand), hot subhumid (dry) eco-region : Malwa plateau, Vindhyan scarpland and Narmada valley, hot dry sub humid with medium and deep clayey Black soils (shallow loamy Black soils as inclusion), high AWC and LGP 150-180 days (AESR 10.1)

Target districts:

First Priority: -

Second Priority: Jabalpur

Selected districts: Sagar

Farming system model:

Crop Production System: Soybean, Sorghum, Chickpea, Maize

Boundary Plantation: *Hardwickia binata, Tectona grandis* , Eucalyptus sps.

Live fence

Outer Layer: *Agave sisalana, Lawsonia alba*

Inner Layer: Leucaena, Gliricidia, Sesbania, *Carissa carandus*

Trees on crop lands

Fodder/green biomass: *Ailanthes excelsa, Leucaena leucocephala, Albizzia lebbeck, Azadiracta indica, Dalbergia sissoo, Albizia amara, Cassia siamia*

Fruit: Mango, Ber, Jamun, caronda,Fig.

Wood (Commercial/Farm Use/Fuel Wood): *Tectona grandis*, Eucalyptus, *Dendro calamus strictus, Leucaena diversifolia, A.nilotica*

Medicinal & Aromatic Plants: *Withania somnifera, Rauvolfia serpentina, Pepaver somniferum, Vetiveria zyzanoides*, Palmarosa.

Vegetables: Bottle gourd, Round melon, Watermelon, Okra, Cowpea, Brinjal.

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Goat, Poultry

Water harvesting techniques: Runoff harvesting in ponds for supplementary irrigation: Design of pond size for catchment size: Efficient use of harvested water: Economic benefits of farm ponds.

Soil and Water Conservation Practices: Manage in 10-100 ha watersheds: Land surface treatment to increase soil water profile torage:Sowing across the slope and ridging later: Contour farming: Graded border strips: Land configuration system: Compartmental bunds for raising crops on conserved soil moisture: Surface drainage: Mulching: Vegetative Barriers: Runoff rainfall model: Erosion versus productivity of soils.

4.26 Model : Agri-horti-silviculture in Semi-arid – *kharif* and *rabi* vertisols

Region : Central highlands (Malwa and Bundelkhand), hot subhumid (dry) eco-region: Vindhyan Scarpland and Baghelkhand plateau, hot dry subhumid with deep loamy to clayey mixed red and black soils, medium to high AWC and LGP 150 – 180 days. (AESR 10.3)

Target Districts:

First Priority: -

Second Priority: Shadhol, Sidhi

Selected districts: Rewa, Satna

Farming system model:

Crop Production System: Rice, Wheat and Chickpea

Boundary Plantation: *A. tortiles, D.sissoo, Eucalyptus.*

Live fence

Outer Layer: *Agave sisalana*, Cactus

Inner Layer: Sesbanea, Leucaena, Gliricidia, *Carissa carandus*

Trees on crop lands

Fodder/green biomass: *Leucaena leucocephala, Albizzia amara, Melia azadirach, Hard wickea binata, Albizia lebbeck*

Fruit: Mango, Ber, Guava, Tamarind, Carissa carandus

Wood (Commercial/Farm Use/Fuel Wood): *Acacia catechu, Acacia auriculiformis*

Medicinal & Aromatic Plants: Safed musli, Palmarosa, *Withania somnifera, Papaver somniferum, Vetiveria zyzanoides*

Vegetables : Brinjal, Chilli, Cowpea, Okra, Bottle gourd, Round melon.

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes and Goats

Water harvesting techniques: Manage in 100-1000 ha watersheds: Large scale soil and water: conservation practices: Contour farming Inter-plot water harvesting: Raised bed and sunken system: Provision for drainage: Design of Structures: Drainage terraces on slope 2-6%: Graded trenches (16-33%): Terraces with dry rubble gravel or lateritic pitched wall: Stream bank protection: Flood mitigation: Surface and subsurface drainage and Erosion Versus Productivity

Soil and Water Conservation Practices: Design of small dams and Efficient use of Irrigation: water for winter crop

Groundwater Exploration: Groundwater recharge systems from percolation tanks: Efficient use of groundwater for sustained purposes

4.27 Model : Agri-horti-silviculture for sub-humid Chattisgarh Region

Region : Central highlands (malwa and Bundelkhand) sathpura range and wain ganga very hot moist sub humid with shallow to deep loamy to clayey mixed red and black soils low to medium AWC and LGP 180-210 days (AESR 10.4)

Target Districts:

First Priority
Second Priority: Mandla
Selected districts: -

Farming system model:

Crop Production System: Rice, Finger millet, Black gram

Boundary Plantation: *Tectona grandis, Acacia nilotica, E. tereticornis, Madhuca latifolia*

Live fence

Outer Layer: *Inga dulce*, Cactus, Zyzyphus

Inner Layer: Leucaena, Sesbania, Gliricidia

Trees on crop lands

Fodder/green biomass: *Albizia lebbeck, Leucaena leucocephala*, *D.sissoo, Azadirachta indica*, Sesbania, Pongamia**,** *Terminalia*

Fruit: Mango, Ber, Lemon, Tamarind, Jackfruit

Wood (Commercial/Farm Use/Fuel Wood): *A.nilotica,* Eucalyptus, *Hardiwickia Binata, Dendrocalamus*

Medicinal & Aromatic Plants: Rauvolfia, Palmarosa*, Papaver somniferum*, Liquorice, Safedmusli

Vegetables: Tomato, Okra, Bottle gourd, Ridgegourd, Amaranth

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Male, Buffaloes

Water harvesting techniques: Developing Aquaculture in high-rainfall: double-cropped regions with rationalization of area under rice

Soil and Water Conservation Practices: Manage in 100-1000 ha watersheds: Large scale soil and water conservation practices: Inter-plot water harvesting: Raised bed and sunken system: Provision for drainage Systems: Design of structures: Absorption type/bench terracing: Erosion Versus Productivity: Irrigation Projects: Embankment type water harvest structures: Design of small dams: Efficient use of irrigation water for winter crop

Groundwater Exploration: Groundwater recharge systems from percolation tanks: Limited use of groundwater for sustained purposes

4.28 Model : Agri-horti-silviculture for sub-humid Chattisgarh Region

Region : Moderately to gently sloping Chattisgarh / Mahanadi basin, hot moist / dry subhumid transitional with deep loamy to clayey red and yellow soils, medium AWC and LGP150 – 180 days. (AESR 11.0)

Target Districts:

First Priority

Second Priority: Raigarh, Rajnandgaon, Gumla

Selected districts: Raipur, Bilaspur, Hazaribagh

Farming system model:

Crop Production System: Rice, Finger millet, Black gram

Boundary Plantation: *E. tereticornis, D.sissoo, Madhuca latifolia*

Live fence

Outer Layer: Cactus, Zyzyphus

Inner Layer: Leucaena, Sesbania

Trees on crop lands

Fodder/green biomass: *A. lebbeck, Leucaena leucocephala*, *D.sissoo, A.indica*, Sesbania, Pongamia

Fruit: Ber, Mango Sapota, Tamarind, Fig

Wood (Commercial/Farm Use/Fuel Wood): *A.nilotica,* Eucalyptus, *Hardiwickia binata.*

Medicinal & Aromatic Plants: *Papaver somniferum*, Rauvolfia, Liquorice, Safedmusli, Palmarosa

Vegetables: Tomato, Okra, Bottle gourd, Ridgegourd, Amaranth, Drumstick

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Male, Buffaloes

Water harvesting techniques: Developing Aquaculture in high-rainfall: double-cropped regions with rationalization of area under rice

Soil and Water Conservation Practices: Manage in 100-1000 ha watersheds: Large scale soil and water conservation practices: Inter-plot water harvesting: Raised bed and sunken system: Provision for drainage Systems: Design of structures: Absorption type/bench terracing: Erosion Versus Productivity: Irrigation Projects: Embankment type water harvest structures: Design of small dams: Efficient use of irrigation water for winter crop

Groundwater Exploration: Groundwater recharge systems from percolation tanks: Limited use of groundwater for sustained purposes

4.29 Model : Agrihorti-silvicuture in Sub-humid *kharif* and *rabi* inceptisols in Indo-Gangetic Plain Region

Region : Moderately to gently sloping Chattisgarh / Mahanadi basin, hot moist / dry subhumid transitional with deep loamy to clayey red and yellow soils, medium AWC LGP150 – 180 days. (AESR 11.0)

Target Districts:

First Priority: -

Second Priority: -

Selected districts: Varanasi, Mirzapur

Farming system model:

Crop Production System: Rice, Pearl millet, Chickpea, Wheat

Boundary Plantation: *D.sissoo, Tectona grandis,* Eucalyptus

Live fence

Outer Layer: *Lawsonia inermis* Cactus, *Agave sisalana*

Inner Layer: *Carissa carandus*, Leucaena, Sesbania, Moringa

Trees on crop lands

Fodder/green biomass: *Luecaena leucocephala. Azadirachta indica, Albizia lebbeck, Bauhinia purpurea, A. procera, B.monosperma, A.amara, D.sissoo*

Fruit: Guava, Amla, Ber, Mango, Bael, Jamun

Wood (Commercial/Farm Use/Fuel Wood): *Dendrocalamus*, Eucalyptus,Teak

Medicinal & Aromatic Plants: *Pepaver somniferum, Cymbopogan flexuosus,* Psoralea, Palmarosa, *Vetiveria zyzanoides,*

Vegetables: Bottle gourd, Brinjal, Chillies, Cluster bean, Cow pea, Round melon

Livestock Production System: Female Cattle, Female Buffaloes, Male Cattle, Sheep, Goat, Poultry

Water harvesting techniques: Manage in 100-1000 ha watersheds: Large scale soil and water conservation practices: Contour farming Inter-plot water harvesting: Raised bed and sunken System: Provision for drainage, Design of Structures:Drainage terraces on slope 2-6%: Graded trenches (16-33%): Terraces with dry rubble gravel or lateritic pitched wall: Streambank protection: Flood mitigation: Surface and subsurface drainage:Erosion Versus Productivity.

Soil and Water Conservation Practices: Design of small dams: Efficient use of irrigation water for winter crop:Groundwater Exploration: roundwater recharge systems from percolation tanks: Efficient use of groundwater for sustained purposes.

4.30 Model : Agri-horti-silviculture in Sub humid *kharif* oxisols in Eastern Ghat Region

Region : Eastern Plateau (Chhotanagpur) Eastern Ghats, hot subhumid eco-region: Gujrat Hills, Dandakaraanya and Eastern Ghats, hot moist subhumid Eco Sub Region with deep loamy Red and Lateritic soils, low to medium AWC and LGP 180-210 days (AESR 12.1)

Target Districts:

First Priority: Koraput
Second Priority: Keonjhar
Selected districts: Bolangir, Dhenkanal, Kalhandi, Phulbani, Sambalpur

Farming system model:

Crop Production System: Rice, Green gram, Sesame

Boundary Plantation: *Gmelina arborea, Tectona grandis.*

Live fence

Outer Layer: Agave, Cactus
Inner Layer: *Erythrina variegata, Glyricidia sepium, Murraya coenigi*, Sesbania.

Trees on crop lands

Fodder/green biomass: *P.pinnata, Albizia sps, Cassia siamea, Grevellea robusta, D.sissoo, Azadirachta indica*

Fruit: Mango, Jack fruit, Guava, Lime

Wood (Commercial/Farm Use/Fuel Wood): *Eucalyptus grandiflora, Acacia auriculiformis*

Medicinal & Aromatic Plants: *Vetiveria zyzanoides, Cymbopogan flexuosus,* Palmarosa, *Solanum viarum*, Cinnamon, Citronella java.

Vegetables: Bottle gourd, Brinjal, Ridge gourd, Water melon, Long melon, Bitter gourd, Tomato

Livestock Production System: Female cattle, Male cattle, Goat

Water harvesting techniques: Runoff rainfall model: Design of pond size for catchment size: Runoff harvesting ponds: Efficient use of harvested water for supplementary irrigation: Economic benefits of farm ponds.

Soil and Water Conservation Practices: Manage in 10-100 ha watersheds: Large scale soil and water conservation practices: Land configuration to increase soil water profile storage: Bench terracing: Compartmental bunds for raising crops on conserved soil moisture: *In situ* conservation of soil moisture: Sowing across the slope and ridging later: Contour farming: Graded border strips: Erosion versus productivity of soils.

Groundwater Exploration: Fluctuation of groundwater levels: Design of percolation tanks for recharging groundwater: Feasibility studies on recharging of groundwater: Extended use of groundwater for irrigation.

4.31 Model : Agri-horti-silviculture in Sub humid *kharif* oxisols in Bihar

Region : Chhotanagapur Plateau and Gujarat hills, hot, dry sub humid with moderately deep to deep loamy to clayey red and lateritic soils, medium AWC and LGP 150-180 days. (AESR 12.3)

Target Districts:

First Priority

Second Priority: Singhbhum west

Selected districts: Ranchi

Farming system model:

Crop Production System: Rice, Fingermillet and Blackgram

Boundary Plantation: *Gmelina arborea*, Eucalyptus

Live fence

Outer Layer: Cactus, Lawsonia

Inner Layer: Leucaena, *Gmelina arborea, Tectona grandis*

Trees on crop lands

Fodder/green biomass: Leucaena, *B.monosperma, A. indica, D.sissoo, A.procera, Pongamia pinnata, B. variegata*

Fruit: Mango, Phalsa, Jamun, Ber, Fig, Bael

Wood (Commercial/Farm Use/Fuel Wood): *A. catechu, T. grandis, A .auriculiformis*, Eucalyptus, *A.mangium*

Medicinal & Aromatic Plants: *Ravoulfia serpentina,* Palmarosa, *Vetiveria zyzanoides, Papaver somniferum*

Vegetables: Bottle gourd, Ridge gourd, Bitter gourd, Water melon, Cowpea, Brinjal, Okra, Papaver somniferum

Livestock Production System: Female Cattle, Male Cattle, Female Buffaloes, Male Buffaloes Sheep and Poultry

Water harvesting techniques: Developing Aquaculture in high-rainfall: double-cropped regions with rationalization of area under rice:

Soil and Water Conservation Practices: Manage in 100-1000 ha watersheds: Large scale soil and water conservation practices: Inter-plot water harvesting: Raised bed and sunken system: Provision for drainage Systems: Design of structures:Absorption type/bench terracing: Erosion Versus Productivity: Irrigation Projects: Embankment type water harvest structures: Design of small dams and Efficient use of irrigation water for winter crop

Groundwater Exploration: Groundwater recharge systems from percolation tanks: Limited use of groundwater for sustained purposes

4.32 Model : Agri-horti-silviculture in Sub-humid *kharif* and *rabi* inceptisols in Indo-Gangetic Plain Region

Region : Eastern plain, hot subhumid (moist) eco-region : North Bihar and Avadh plains, hot dry to moist subhumid with deep, loamy allvium derived soils, low to medium AWC and LGP 180 – 210 days. (AESR 13.1)

Target Districts:

First Priority

Second Priority

Selected districts: Bahraich

Farming system model:

Crop Production System: Rice, Pearl millet, Chickpea and Wheat

Boundary Plantation: Eucalyptus, *Tectona grandis, A.nilotica.*

Live fence

Outer Layer: Lawsonia, *P. juliflora*

Inner Layer: Leucaena, *Sesbania grandiflora, Carissa carandus*

Trees on crop lands

Fodder/green biomass: *Leucaena leucocephala, Sesbania grandiflora, D.sissoo, P. pinnata, H.binata, Bauhinia*

Fruit: Guava, Amla, Phalsa,Bael,Jamun

Wood (Commercial/Farm Use/Fuel Wood): Eucalyptus, *Tectona grandis*, Dendro calamus.

Medicinal & Aromatic Plants: *Papaver somniferum*, Palma rosa, *Vetiveria zyzanoides, Cymbopogan flexuosus*

Vegetables: Brinjal, Tomato, Okra, Bottlegourd, Round melon, Chillies.

Livestock Production System: Female Cattle, Female Buffaloes, Male Cattle, Sheep, Goat, Poultry

Water harvesting techniques: Runoff harvesting in ponds for supplementary irrigation: Design of pond size for catchment size: Efficient use of harvested water: Economic benefits of farm ponds

Soil and Water Conservation Practices: Manage in 10-100 ha watersheds: Land surface treatment to increase soil water profile storage: Sowing across the slope and ridging later Compartmental bunds for raising crops on conserved soil moisture: Contour farming: Graded border strips: Soil conservation: Leveling of humps: Gully beds and sides: Bench terracing on gully sides: Widening of gully beds: Earthen/masonry check dams: Runoff rainfall model Erosion vs productivity of soils.

4.33 Model : Agri-horti-silviculture in Dry sub-humid sub montane *kharif* and *rabi* incepti/entisols in Shivalik Region

Region : South Kashmir and Kumann Himalayas Warm moist to dry sub-humid with shallow to medium deep loamy soils; low to medium AWC and LGP 150-210 days. (AESR 14.2)

Target Districts:

First Priority:

Second Priority:

Selected districts: Jammu

Farming system model:

Crop Production System: Maize, Wheat , Fruit and Vegetable

Boundary Plantation: *Populas deltoides*, *Gmelina arborea, Grewia optiva*

Live fence

Outer Layer: Poplar, Zizyphus sps.

Inner Layer: Leucaena, *D.sissoo*, Glyricidia.

Trees on crop lands

Fodder/green biomass: *Grewia optiva, D.sissoo* Leucaena, *Butea monosperma, A.lebbeck, Ailanthus excelsa, Bauhinia purpuria, Anogeisus latifolia*

Fruit: *Aegle marmalos [bael]* , Jamun, Phalsa, Mulberry, Ber.

Wood (Commercial/Farm Use/Fuel Wood): *A.catechu,* Eucalyptus, Poplar, *Leucaena diversifolia*

Medicinal & Aromatic Plants: Spear mint, Japanese mint, Celery, *Ocimum viride*

Vegetables: Tomato, Chillies, Brinjal, Cow pea, Cluster bean, Long melon, Amaranth

Livestock Production System: Cattle Female, Buffaloes Female , Cattle Male, Goat

Water harvesting techniques: Manage in 10-100 ha watersheds: Design of pond size for catchment size for runoff harvesting in ponds: Efficient use of harvested water for supplementary irrigation: Economic benefits of farm ponds.

Soil and Water Conservation Practices: Water harvesting Land surface treatment to increase soil water profile storage: Contour farming (cultivation and sowing along contour): Sowing across the slope and ridging later: Bench terracing: Compartmental bunds : Graded border strips : Runoff rainfall model: Erosion versus productivity of soils: Gully beds and sides: Cover crop management through intercropping.

Groundwater Exploration: Fluctuation of groundwater levels: Feasibility studies on recharging of groundwater: Design of percolation tanks for recharging groundwater: Limitation on use of groundwater for irrigation.

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Annexure

An example of expected returns

District: Raipur

AER: 11.0

Trees:

On boundary and bund: Eucalyptus and Leucaena
On crop land: *A. nilotica*
Crops: Rice-Blackgram

Returns (approx.) per ha

Year	Eucalyptus	Leucaena	A. nilotica	Crop 1	Crop 2	Total returns
1	0	0	0	12000	10000	22000
2	0	0	0	11400	9500	20900
3	0	4240	0	10800	9020	24060
4	0	5300	0	10284	8570	24154
5	0	5300	500	9768	8140	23708
6	0	5300	600	9276	7730	22906
7	20000	5300	700	8808	7340	42148

Assumptions:-

1. No. of *A. nilotica* trees/ha : 200
2. No. of Eucalyptus trees on boundaries : 100
3. No. of Leucaena plants in inner layer of fence (0.75 m spacing) : 530
4. Income per Eucalyptus tree : Rs. 200 (7^{th} year)
5. Income from Leucaena (fodder) : Rs. 8/tree during III year
   Rs. 10/tree IV-VII year
6. Income from *A.nilotica* tree : Rs. 500/ha (from V year onwards)
7. Rice yield : 2 t/ha
   Sale price per kg : Rs. 6
8. Blackgram yield : 1000 kg/ha
   Sale price per kg : Rs. 10

Note: 1. There is 5% reduction in area under crop form II year onwards due to shade effect of trees.

Source: Planning Commission (2001), Viswanath *et al* (2000). (suitably modified for rainfed situations).

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