Alternate Land Use Based Farming systems in Rainfed Agriculture

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1. Inrroduction

Rainfed Agriculture has a crucial role to play in the economy and food security of India. At present, about 60% of the net sown area is rainfed, contributing 40% of the total food production; it supports 40% of human, and 60% of livestock population. However, climate change, aberrant behavior of monsoon rainfall, land /soil degradation (70 m ha) with multiple nutrient and water deficiencies, declining the ground water table and poor resource base of the farmers are principle constraints for low and unstable yields in rainfed areas   Increasing crop productivity to meet food , fodder, fuel, timber and fruit requirements of teaming millions in our country poses a greater challenge. In this context, there is a need to enhance the productivity of rainfed crops from at least 1 to 2 t to meet the food requirements by 2020 AD. .   Therefore **integrated farming systems** assumes a greater importance for sound management of farm productivity, reducing environmental degradation, improve the quality of life of the resource poor farmers and sustainability in rainfed regions.

A **farming system** is defined as a population of individual farm systems that have broadly similar resource basis, enterprise patterns, household livelihoods and constraints and for which similar development strategies and interventions would be appropriate.   Depending on the scale of the analysis, a farming system can encompass a few dozen or many millions of households .In a farming system, the farm family is also intimately linked. Farming system is holistic in its scope. It is based on the ecological, economic and demographic considerations. Farming systems provide for better utilization of resources and provide for maximization of returns to the owned or internally generated resources. Farming systems also help in mitigating the impact of drought on the income and thereby by livelihoods of the farmers.

2.0 Farming systems and watersheds

2.1 Planning watershed based Farming system

Farming systems approach in watershed is a method designed to understand the farmers, priorities, strategies and allocation of enterprises and decision-making. It should start with knowledge, problems, analysis and priorities of farmers in given hydrological unit. This approach should relate to the land use that results in an efficient, optimize and sustainable use of natural resources including biotech, socio-economic and related infra-structural resources.

2.2 Components in watershed based farming systems

Traditionally farmers in rainfed agriculture are following mixed farming practices to spread the risk and produce of various commodities in watersheds. With evaluation of market oriented farming most of the earlier production systems gave way monoculture of arable crops. Single crop based farming make the farmer dependent on the market for other essential inputs like fodder, fiber, fuel wood, and timber. With appropriate farming systems majority of the needs of the farmers can meet within the production system. Livestock forms an integral part of the farming systems in most rainfed areas. Neglect of fodder production resulted in acute fodder scarcity leading to poor livestock health and quality**.**

Keeping the above facts in view, the rainfed farming system model for small and marginal farmers (1-2 ha) should include the components of :

- Arable crops (cereals, oilseeds, pulses) in class IIandIII lands (Middle of watershed) to meet the food requirement of the family,
- fodder crops on degraded lands (classIV and classIVII—top of watershed area)) and field boundaries to meet feed needs of the cattle. Economic bushes for higher income in marginal lands.
- Horticulture crops (fruit and vegetable trees) to maintain nutritional security of the farm family besides earning some income to meet felt needs of the farm family. Class II and III-lower end of the watershed)
- A well-developed farmstead area covering small and large ruminants (diary, sheep/goat, poultry, piggery, apiry) to provide year round flow of small income and for higher employment opportunities.

The area in the model farm should be systematically treated with field bunds across the slope covering with multi-purpose trees / bushes to reduce the dependence on external inputs (chemical fertilizers and feed). Creating farm ponds at strategic location can do water harvesting to improve the productivity of horticultural components in the system.

3. Alternate land use and farming systems

To cope up increasing population of both human and livestock and rising demand for food, fodder and fibre, more and more marginal, sub marginal lands are brought under cultivation. These lands are unable to sustain productivity, cultivating such lands leads to imbalances in the ecosystem. In order to demand of food and fodder and conserve natural resources, a diversified land use system need to be adopted in different agro ecological   regions of the country as an alternative to conventional cropping systems. Through this approach, the biological productivity and quality of resource base degraded ecosystems can be significantly enhanced. When land put under an alternative   production system in order to match its capability more appropriately to the new land use and achieve more sustainable biological and economic productivity on long term, it is known **as alternative land use.** Depending upon component of farming system, various types of land use can be integrated on water shed system mode

Agroforestry (AF) is a collective name for land-use systems in which woody perennials (trees, shrubs, palms, bamboos etc.) are deliberately grown in association with herbaceous plants (crops, pastures) or livestock, in a spatial arrangement, a rotation, or both; there are usually both ecological and economic interactions between trees and other components of the system" It can be classified into agrisilviculture, alleycropping, agrihorticulture, sivipasture and hortipasture etc., depending on nature of the component in the system. Tree farming, social forestry are other alternative land uses which are meant to improve the degraded natural base besides providing ecionomic products to the community**.** It is aimed to optimize the use of resources through recycling, internalize the input production**,**, reduce the risk and conservation of natural resources. It reduces the erosivity of rainfall and erodability of soil through dissipation of energy of raindrops by canopy and improves the soil organic matter, physic-chemical and biological properties of soil. Alley cropping with leucaena /Glyricidia hedges and grass barriers have been found effective in controlling erosion upto 30% slope under humid, sub-humid and subtropical climatic conditions

3.1 Agri-horticultural systems: Among various land use systems, agri-horti system is most important in terms of economic returns to the farmers and also farmers preference. In various agroforestry systems evaluated in Andhra Pradesh, agri-horticulture was found to be most profitable giving CB ratio of 1:5.53 followed by silvipasture and agri silviculture. In sub mountain region of Dehradun peach based agri hortisystem recorded higher returns over sole tree. In semi arid regions of central and southern India, many agri horticultural systems have been evaluated and founf more profitable than arble crops and fruit trees alone 17.5% of crude). At CRIDA, the horti-pastoral system with *Cenchrus / Stylos* in rainfed guava and custard apple, *Cenchrus* yielded dry forage 7 t/ha with protein during the first year while *stylos* recorded 5.6 tons of dry fodder during the second year of plantation. In Ber based agri-horti system Pearlmillet + pigeonpea (Solapur, Pigeonpea + blackgram (Rewa), Castor (Dantiwada) and Clusterbean (Hyderabad) showed promising results in rainfed environment. Ber on an average gave 40 kg fruits/tree along with the 100 kg of horsegram and 450 kg of cowpea cultivated in interspaces The Agri-horti-silvi-duckery-fishery system studies North East India showed that multi enterprise model comprising cereal crops, pulses, oil seeds, horticultural crops such as mango and pineapple, vegetables crops and livestock components of duckery, piggery, and fishery with harvesting structures in 1 ha land gave 5 times more profitable than traditional mono crop rice cultivation which gave maximum production of 1t/ha of rice (Rs.5000-6000/ha/year).

3.2 Horti-pastoral systems Horti pastoral system is a combination of fruit trees and pasture or legume. It is ideal land use option for degraded lands. In Guava based hortipastoral system at CRIDA, yield reduction of stylo was less under widely spaced trees (8x5 m) compared to closer spacing (5x5m), indicating the necessity of wider spacing of fruit trees when grown with stylo, Buffel grass out yielded stylo and took less time for establishment.

3.3 Slope Agriculture Land Technology The method of growing seasonal and perennial crops in 3m to5m wide bands between contour rows of Nfixing trees is called as Slope Agricultural Land Technology (SALT). The N fixing trees are thickly planted in double rows to make hedge rows. When hedge is 1.5 to 2m tall, it is lopped to about 40cm height and the loppings are placed in alleys to serve as mulch cum manure. This practice improves soil organic matter and other physic-chemical properties in the hill and mountain system

3.4 Agri-silviculture system:It is recommended for land capability class IV with annual rainfall of 750 mm. A large number of tree-crop combinations, particularly of N, fixing trees with sorghum, groundnut, castor and pulses were evaluated in Alfisols and Vertisols. Short duration dryland crops such as perarlmillet, blackgram and greengram, combined with widely spaced tree rows of *Faiderbia albida* and *Hardwickia binata*, have been found compatible in semi-arid tropical areas

3.5 Tree Based Farming: The marginal lands or the lands, which are not capable of supporting the field crops, can be best converted into the tree-based farming. With the treatment measures, soil fertility and moisture level can be enhanced. With the availability of water for protective irrigation orchards, agr-horti-forestry becomes viable option in such area.

3.6 Live fence rows: Fence row areas are important in most uplands of small farm size in rainfed lamds. 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 . 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 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 system.
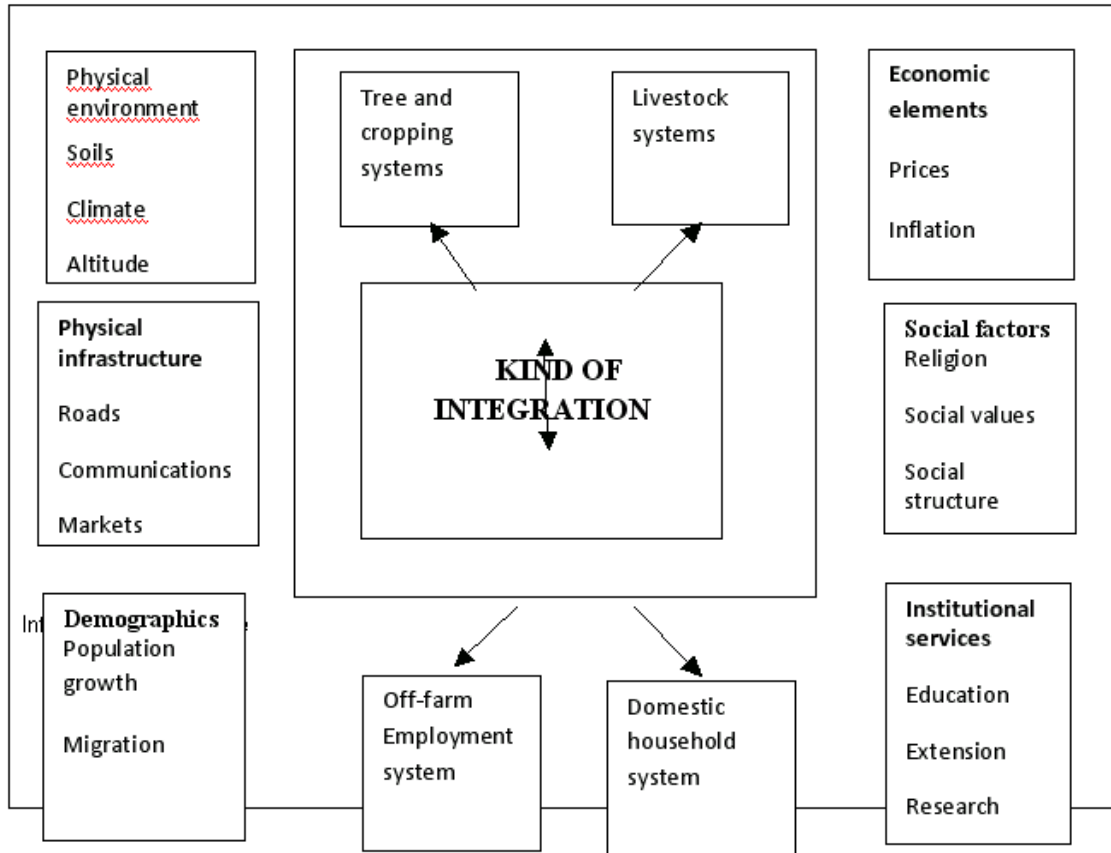
Fig. Integration of Alternate land use systems and livestock in farming systems

3.7 Trees as hedges: There are several trees that are taken as live hedges by the farmers. Some examples are given hereunder

Common name	Botanical name	Uses
Sisal agave	*Agae sisalana*	Non-browsable, drought-resistant, yields twines, used in ship-cordage, webbing and sacking, paper making, hardware production, also useful in erosion control (Gully checks)
Shkikai	*Acacia rugata*	Yields fuel, reduces soil erosion and serves as cleaning powder
Agave	*Agave cantala*	Non-browsable, checks soil erosion, of commecial value, used in rope making, cordage, mats, twines and nets

Molucca bean	*Caesalpinia crista*	Reduces soil erosion
Coral tree	*Erythrina variegata*	Non-browsable, soil and water conservation
Thor	*Euphorbia* sp	Non-browsable, of medicinal value
Jatropha	*Jatropha carcus*	Non-browsable, soil and water conservation
Lantana	*Lantana camara*	Non-browsable, resistant to adverse conditions, improves fertility of exhausted areas and rocky gravelly or hard infertile soil, used in soil conservation, adds humus, green manure, convertible to compost
Kewada	*Pandanus odoratissimus*	Non-browsable, soil binder, controls erosion from wind and water, shelter belt to sand drifts, of food value, used in making paper, ropes, cordage, hats, baskets, umbrellas and fancy articles, roots for brush an basket making
Horse bean	*Parkinsonia aculeate*	Used as fuel, fodder, paper making, of medicinal value
Vilayati babul	*Prosopis juliflora*	Immunity to grazing, yields firewood, fodder.

4.0 Crop based farming systems:

The cropping pattern with 35.39% of food grains and 25.71% of pulses 20.7% of oilseeds, 17.3% of commercial crops and 1.17% of fodder crops in total holdings of small farmers with backyard poultry (6 birds) helped the farmers to stabilize the farm income at Dharwad The animal component (Poultry bird) helped the farmers during the drought year to stabilize the farm income as compared to crop alone.

The farming system module initiated in 1.14 ha area of watershed at CRIDA comprises arable cropping of sorghum + pigeonpea, castor + cluster bean and sole pearl millet and pigeonpea (40.9%) grasses (9.9%) agro-forestry of aonla + cowpea, pongamia + cowpea and custard apple (28.62%). Bushes of curry leaf and jatropha (9.65%) area allocated during this year. The henna and teak were grown along with periphery of watershed area. The results during second year indicated that arable crops in different systems contributed to the gross income of Rs.6189 along with net income of Rs.3728 with 2.51 BC ratio in 0.47 ha area, while grasses covering 0.12 ha area gave Rs.1423 grass income and Rs.978/- net income, respectively. The agro-forestry options planted in watershed area (0.33 ha) recorded the gross and net income of Rs.3277 and 1880 respectively. The horticulture interventions with 0.10 ha gave the gross income of Rs.4967 and net income 3547. The bushes covering 0.11 ha realize the gross income of Rs.400/- Thus the farming system module covering crops, grass, agro-forestry and bushes interventions gave the total gross income of Rs.18286 and net income of Rs.11380 with BC ratio of 2.65 for 1.13 ha area. The biomass of 5367 kg was produced as a fodder, which will be sufficient to feed two livestock (dairy) or 10 sheep during the entire period within a year.

5.0 Crop Diversification

In rainfed agriculture, sustainability of yield becomes more important. While considering rainfall, and sustainable yield index it was observed that rice + raddish (4:1) and rice + blackgram (4:2) in oxisols of Phulbani, pigeonpea + okra (1:1), maize + okra (1:1) in dry sub-humid inceptisols of

Ranchi, sorghum + cowpea (F) under delayed sowing conditions of Arjia, pearlmilelt + pigeonpea (1:2) in vertisols of Solapur, sunflower + pigeonpea 2:1) in vertisols at Indore and greengram + castor in semi-arid entisols of Dantiwada recorded higher sustainability over the sole cropping.

Crop diversification in rainfed regions aims to make rainfed agriculture achieving nutritional security (human and animal and crops), more employment and income generating, eco-friendly and poverty alleviation and comparative advantage in the trade   In cotton based production system at Akola, the conventional crops are cotton, sorghum, greengram, blackgram can be substituted up to certain extent by growing vegetables (coriander, clusterbean, okra). Floriculture with marigold can reap higher profitability. In *rabi* sorghum dominant areas, chillies + cotton (1:1), chillies + onion can be practiced in lieu of chillies at 60 cm row spacing during *kharif*, then sowing of cotton in the intra row of chillies. Similarly, small millets (foxtail millet)/ prosomillet / little millet can be grown with the onset of monsoon as a bonus crop in *rabi* sorghum areas. The mono-cropping of groundnut in Anantapur areas can be substituted partially by intercropping systems of groundnut + pigeonpea (8:!) and groundnut + castor.

A matrix of possible land use/crop diversification as influenced by resource carrying capacity is recommended in rainfed environment **(Fig.1).** It is aimed to optimizeof resources through the principle of recycling, internalize the input production
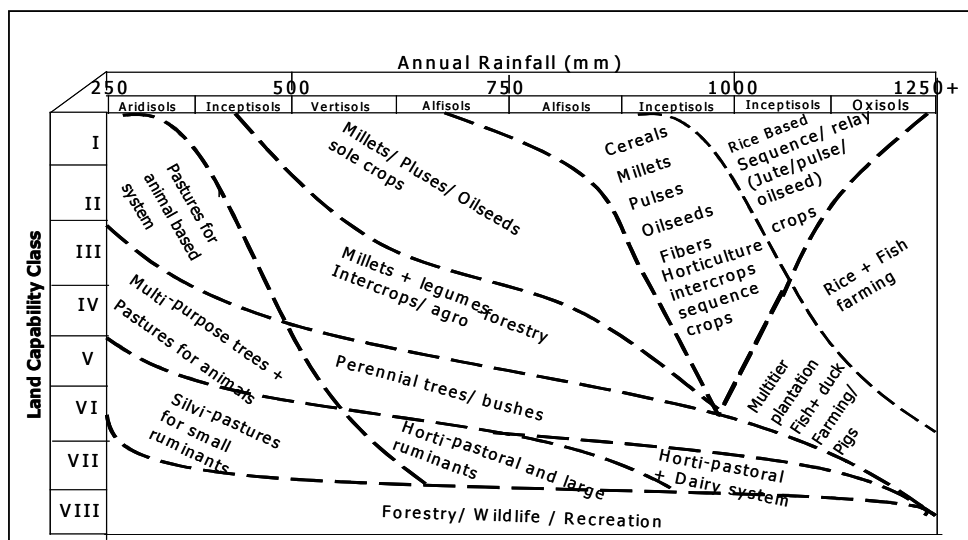
Productive farming system matrix in rainfed agriculture

Medicinal and Aromatic Plants: Cultivation of high value and low volume crops for dyes, medicines and aromatics is economical in rainfed lands.   They also played a vital role in sustained use of degraded lands.   These perennial and annuals with plants mostly of bushy nature.   The advantage of bushes over larger perennials is that the former offers less competition to associated crops. The promising plants for cultivation in drylands are dyes like Indigo (*Indigofera tinctoria* L.), Henna (*Lawsonia innermis* L.) and Bixa (*Bixa orellana* L.), Meidcinal plants like Ashwagandha (*Withania somnifera* (L.) Dunal), Senna (*Cassia angustifolia Vahl.*), Mucuna (Mucuna pruiens (L.) Spreng), lemon grass (*Cymbopogan winki* (DC) Stapf), palma rosa (*Cymbopogan martini* (Roxb.) Wats), and sweet basil (*Ocimum basilium* L.)

6.0 Value addition in Farming Systems

Post harvesting, processing and establishment of market links is the key dimension of farming systems program. The collective procurement, value addition, and marketing of the products can directly be handled by the producers through their own organization. Establishment of agro service centers in the villages can save the cost of inputs and also can get précised farm advisory services for higher profitability. Formation of commodity groups and self-help groups for farm women can help to promote off-season income generation activities which leads to livelihood improvement in villages.

The approach of family focused development through tree based farming integrated with other on-farm and off-farm interventions is popularly known as "Wadi" (Gujrati term for orchard). Presently, the wadi program is benefitting over 100,000 families spread over Gujarat, Maharashtra, Karnataka, Rajasthan, Uttar Pradesh and Madhya Pradesh. The model evolved over a period of two decades has become very comprehensive and good approach for sustainable livelihood and better quality of life in the farming community.

7.0 Women Empowerment in Farming Systems

With the organization of women Self Help Groups (SHG), micro-credit could be availed to meet their consumptive and production needs of the farming system. They are skill improvement of farm women in fruit and forest nursery management, mushroom production, vermin-composting, vegetable production, sericulture, share cropping on lands owned by non-participating families, food processing and oilseed collection, backyard poultry and piggery not only improve the income of farming community but also enhance the employment opportunities in rural areas. The skill improvement for landless farming community in respect of agriculture, animal husbandry and horticulture reduce the drudgery of the farmwomen and also a source for livelihood improvement.

8.0 Farmers' led learning process

Farm households have a great potential for experimentation, learning and exchange of experiences on farming systems. In order to improve the livelihood of the farming community, there is a need to understand strength and weaknesses of the traditional farming systems. This can be done by documentation in different rainfed environments to initiate on-farm farmers' participatory farming system research program. The next important step is to improve the existing farming systems with low external inputs for higher total factor productivity and income generation. There is a need to recognize gender and youth roles to develop appropriate farming systems in rainfed areas. The wide spread adoption of participatory methods for planning analysis and implementation should be linked with relevant public sector services like banks, input agencies, industries and markets. Under decentralization, planning and implementation should be better tailored to the diverse needs of local farming systems. There is a need to identify broad range of financial and marketing organization in order to address diverse needs of farmers, particularly to those associated with chronic poverty and hunger.

Table 1. Rainfed Farming System Modules in different AICRPDA Centers

Production system/AESR/ Soil Climate	Area of Domain	Potential Farming system module
Arid		
Groundnut – Anantapur AESR 3. Red soils with 669 mm	*Kharif* arid shallow alfisols with 616 mm annual rainfall, LGP 60-90 days, Target domain – Rayalaseema (Anantapur, Kurnool and Chittoor districts).	Groundnut + Pigeonepa (11:1). Crop + livestock (sheep @10/ha system of farming Boundary plantation – Azardiracta indica, Eucalyptus camaldulensis, Acacia nilotica Live fence Outer layer : Eucalyptus, Agave Inner layer : Glyricidia Trees on crop plants : Fodder production :D.sissoo, glyricidia Fruit trees: ber, custard apple, pomegranate, amla + *kharif* spreading crops Wood (Commercial/farm use/fuel wood) : Acacia auriculiformis/Acacia nilotica Livestock : Cattle, Buffaloes, Sheep, goat, poultry
Groundnut - Rajkot AESR.2.4, Kharif blacksoils with 350 to 600mm	*Kharif arid deep vertic/vertisols, with 350 to 670 mm rainfall. Target domain north saurashtra agro-climatic zone having LGP 60 to 120 days.*	Subabul (paired row) + sorghum (5-6), subabul + groundnut, perennial pigoenpea (alleys) + groundnut Fodder /Biomass on sloppy fallow landcs, grow Dicanthium annulatum, Leucaena and pongamia Fruit crops: Custard apple, mango, pomegranate, phalsa, fig, jamun and tamarind Boundary plantation – Prosopis cineraria, Acacia nilotica, Lawsonia Live fence- Outer layer : Lawsonia alba, Inner layer : Prosopis cineraria Trees on crop plants – Fodder/Green biomass: Dichrostachys cineraria Fruit : Custard apple, Fig, Mango Wood (commercial/farm use/fuel wood) : Acacia Senegal, Acacia nilotica Livestock : Cattle, Buffalo, Sheep, Goat
Pearlmillet - SK Nagar AESR.2.3, Deep aridisols with 550 mm	*Kharif arid deep aridisols covering Sabarkantha, Gandhi Nagar, Banskanth, Mehsana and parts of Patan and Ahmedabd in North Gujarat. Average annual rainfall 550 mm, with LGP 60-90 days.*	Ber + sorghum/greengram to be grown between two rows of ber Pearlmillet + karingdo, sorghum + karingdo (6:1) Ber + sorghum / greengram in between two rows Amla + stylos / Cenchrus/Dicanthium annulatum Senna medicinal
Pearlmillet - Hisar AESR. 2.3. Deep aridisols with 320 mm	*Arid Deep aridisols covering the areas of Hisar, Sirsa, Fatehbad, Bhiwani, Jhajjar, Mahendergarh, Rewari, Gurgaon, Kandi area of Panchkula and Ambala having a total annual rainfall of 320 mm.*	Chickpea paired row (30/60 cm) + Chinese cabage, ber, jetropha + aswagandha / aloevera Boundary plantation – Prosopis cineraria, Acacia tortolis, Eucalyptus Live fence – Outer layer : Prosopis juliflora, Zizyphus mauritiana, Zyziphuz numularia, Inner layer : Dalbergia sissoo, Carissa carundus

Rabi sorghum - Bijapur AESR. 3. Semi-arid medium/deep vertisols with 680 mm	*Semi-arid medium/ deep vertisols with 680 mm of rainfall covering domain districts of Bijapur, Bagalkot and Gulbarga, eastern parts of Belgaum, Lingsugur of Raichur of Karnataka and Southern parts of Maharshtra*	Agri-horti system of rabi sorghum + ber, subabul Acacia nilotica and Dalberja sissoo on degraded soils Pigeonpea + aswagandha / sunflower + aswagandha Amla/custard apple + henna + castor/ pearlmillet /foxtailmillet Sapota + pearlmillet/castor Guava + henna + Seemarisba + grengram Boundary Plantation – Eucalyptus camaldulensis, Tectona grandis Live fence – Outer layer: Agave sisalana, Cactus Inner layer : Leucaena leucocephala, Carrissa carundus, Trees on crop lands – Fodder/green biomass : D. Sissoo, Glyricidia, Albizzia lebbeck, Hardwickia binata Fruit : Mango, Pomegranate Wood (Commercial/farm use/fuel wood) : Eucalyptus bybrid, Acacia auriculiformis
Rabi sorghum - Bellary AESR. 3. Vertisols with 500 mm	*Semi-arid vertisols having the rainfall of 500 mm covering the parts of Chitradurga, Bellary, Raichur districts of Karnataka state and parts of Anantapur (Black soils), Kurnool and Mahabubnagar (black soils) districts of Andhra Pradesh.*	Field beans under delay onset of monsoon Custard apple, ber, aleovera Boundary Plantation – Azadirachta indica, Eucalyptus camaldulensis, Acacia nilotica Live fence – Outer layer: Cactus, Eucalyptus, Agave Inner layer : Glyricidia, 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 Wood (Commercial/farm use/fuel wood) : Tectona grandis, Acacia auriculiformis
Maize - Arjia AESR.4.2. Semi arid shallow to deep vertisols with 656 mm	*Kharif semiarid shallow to deep vertisols with 656 mm of annual rainfall covering districts of Districts of Udaipur, Chittorgarh, Bhilwara, Rajsamand and parts of Ajmer, Banswara nd Dungarpur districts of Rajasthan.*	Maize + blackgram (2:2) Groundnut + sesame (6:2) Mustard + chickpea Jatropha + greengram land capability class (LCC) III lands, silvi-pastoral system with Prosophis cinararia + Cenchrus land capability class (LCC) IV lands, Horti-pastoral system with ber + Cenchrus setigerus Ingadulsis spp (jangal jaalebi) / Acacia tortillas (Israeli babool) Eucalyptus (safeda)/Parkinsonia aculeate (Vilayati kiker)/Prosopis juliflora (Vilayati babool)
Pearlmillet - Agra AESR 4.1. Arid inceptisols with 665 mm	*Semi Arid Inceptisols covering areas of Agra, Aligarh, Hathras, Mathura, Etah, Mainpuri and Firozabad districts of Uttar Pradesh having mean annual rainfall of 665 mm.*	Pearlmillet + pigoenpea (2:1) Ber+green gram/cluster bean/cowpea in between rows of fruit crops. Ber+ pearlmillet for fodder Amla + mustard / Chickpea/barley/lentil Ber+mustard Sarpagandha /Mehandi/ Rajanigandha/Awagandha Boundary Plantation – Azadirachta indica, Albizzia lebbeck, Pongamia 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 Fruit : Mango, Guava, Amla, Phalsa Wood (Commercial/farm use/fuel wood) : Eugenia, Eucalyptus, Acacia nilotica

Kharif sorghum - Hyderabad Kharif rainfed alfisols with 750 mm annual rainfall, LGP 120-150 days,	*Southern Telangana zone (RR district – Nalgonda, Mahaboobnagar, Warangal and parts of Medak district).*	Ber/Amla + greengram, Mango + greengram, guava + groundnut / short duration of pulses, Mango/Guava + Cehchrus ciliaris/Stylosanthes, Leuccaena + Cenchrus ciliaris/stylo, Bush crops (Curry leaf, Jetropha,) and grasses on marginal lands of watersheds, Custard apple + Stylos / Cenchrus, Pongamia, Leucaena, Teak on marginal lands
Fingermillet - Bangalore AESR. 8.2. Semi arid deep alfisols with 607 mm	*Central, eastern, and southern agro climatic zones of Karnataka covering Davanageri, Chikmagalur, Hassan, Mysore, Chamaryanagar, Chitradurga, Tumkur, Kolar, Bangalore (rural and urban) and Mandya districts.*	Faderbia albida ,/Casurina on contour bunds Hibiscus subdarifa + pulses
Soybean - Indore AESR.5.1, Medium to deep vertisols with 900 to 1000mm	*Semi-arid medium to deep vertisols. The region comprises of Mandsaur, Rajgarh, Ujjain, Indore, Dewas, Shajapur, Ratlam, part of Dhar (Badnawar and Sardarpur tehsil), Jhabua (Petlawad Tehsil), and part of Sehore district of Madhya Pradesh. The rainfed farming in the state is 69% of the cultivated area.*	Soybean + pigeonpea (4:2) Fruit trees: Ber (Zizyphus sp.)/ Aonla (Phyllanthus emblica) Drum stick (Moringa poleiferlam) Crops: Soybean + chickpea/Soybean + Pigeonpea (4:2)/Cowpea + chickpea Fodder system- Sorghum /Maize green /Sorghum sudanesis green fodder Boundary Plantation – Gliricidia / Jatropha Live fence – Outer layer: Lawsonia Inner layer : Glyricidia, sesbania, Leucaena Trees on crop lands – Fodder/green biomass : Hardwickia binata, Leucaena Fruit : Ber, Pomegranate Wood (Commercial/farm use/fuel wood) : eucalyptus, Medicinal and aromatic plants : Rauvolfia serpentina, Vetiver zyzanoides, Palma rosa Livestock : Cattle, Buffaloes, Goat, Poultry
Soybean - Rewa AESR.10.3. Sub-humid medium deep vertisols with 1100 mm rainfall	*sub-humid medium deep vertisols. The region comprises of Satna, Sidhi, Shahdol, Umaria and Panna districts, North-eastern parts of Katni, Jabalpur and Dindori districts and Souther parts of Tikamgarh and Chhatarpur districts.*	Coriander + Chickpea (2:7) Wheat + mustard (2:1 or 4:2) Agri-horticulture: fruit crops (mango/guava/amla) + field crops (wheat, barley, pulses and oilseeds) Amla Boundary Plantation – D. sissoo, Eucalyptus Live fence – Outer layer: Agave, Inner layer : Glyricidia, Leucaena Trees on crop lands – Fodder/green biomass : Leucaena, Hardwickia binnata, Fruit : Mango, Ber, Guava Wood (Commercial/farm use/fuel wood) : Acacia sp., Auriculiformis Medicinal and aromatic plants : Vetivera Livestock : Cattle, Buffaloes and goats
Cotton - Akola AESR. 6.3. Black, medium and deep clay loams to heavy clays with 813 mm	*Part of Amaravati, Wardha, Yeotmal, Parbhani, Buldana, east and west Khandesh districts of Maharastra and parts of Adilabad and Nizamabad districts of Andhra Pradesh*	Cotton + sorghum + pigonpea + sorghum (6:1:2:1) for risk minimizing 3 tier intercropping system. Ber + soybean, aonla + blackgram, aonla + soybean + sunhemp, ber + greengram Amla/Ber+Tamarind + crops (cotton, sorghum, soysbean, greengram and blackgram) Aswagandha and marigold

Rabi Sorghum – Solapur AESR. 6.1. Arid shallow to deep vertic inceptisols / ▢ertisols with 723 mm	*Solapur and Ahmednagar, Eastern parts of Nasik, Pune , Satara, Sangli, Dhule and Nandurbar, Western parts of Beed, Osmanabad, Aurangabad, some parts of Jalgaon and Buldana districts.*	Intercropping of hybrid pearlmillet (paired row at 30 cm spacing) with pigeonpea Sunflower + pigeonpea (2:1) Amla +Drumstick+ Pearlmillet/Pigeonpea/Sunflower(alley of amla at 8x8 m2 + Annual drumstick at a distance of 4 m +crops) Custard apple (4 x 4 m) + horse gram Ber + greengram/ clusterbean/ cowpea for grain purpose Ber + pearlmillet (fodder) Boundary Plantation – Glyricidia, Eucalyptus Live fence – Outer layer: Agave Inner layer : Sesbania, Leucaena Trees on crop lands – Fodder/green biomass : D. sissoo Fruit : Pomegranate, Sapota, Custard apple Wood (Commercial/farm use/fuel wood) : Eucalyptus, Anjan, Livestock : Cattle, Buffaloes, Sheep, Poultry, Goat
Rice - Phulbani AESR 12.1. Red and yellow soils with 1597 mm **Rice + Pigeonpea (5:2)**	*Sub-humid Deep Alfisols/Oxisols covering areas of Kandhmal, Boudh, Rayagada, Gajapati and part of Ganjam districts i.e Phulbani, Boudh, Rayagada, Gajapathi and Asoka having a mean annual rainfall of 1597 mm.*	Rice + Pigeonpea (5:2) Maize + Pigeonpea (1:1) Mango + blackgram/niger agri-horti system Pigeonpea +turmeric yam (Diascorea) + maize Sal, Teak in wastelands Boundary Plantation – Gmelina arborea, Tectona grandis Live fence – Outer layer: Agave Inner layer : Glyricidia, Sesbania Trees on crop lands – Fodder/green biomass : Cassia sp, Fruit : Mango, Guava, Lime Tuber crops : Colacassia, Cassava,Yam Wood (Commercial/farm use/fuel wood) : Eucalyptus Spices : Turmeric, Ginger
Rice - Faizabad AESR 9.2. Inceptisols with 984 mm	*Sub-humid Deep Inceptisols covering areas of Faizabad, Sultanpur, Gonda, Basti, Barabanki, Jaunpur, Ambedkarnagar districts of Uttar Pradesh having a mean annual rainfall of 984 mm.*	Maize + Kalmegh /Ashwagandha Maize + Okra/Taroi/ Turmeric/ Ginger Boundary Plantation – Acacia nilotica, Hardwickia binata Live fence – Outer layer: Eucalyptus Inner layer : Sesbania, Leucaena Trees on crop lands – Fodder/green biomass : Leucaena, Sesbania Fruit : Mango, Amla, Ber, Bael Wood (Commercial/farm use/fuel wood) : Eucalyptus Medicinal and aromatic plants : Vetivera, Cimpogaon Livestock : Cattle, Buffaloes, Goat, Poultry

Rice - Varanasi AESR 9.2. With hot sub humid deep inceptisols with 1080 mm	*Sub-humid Deep Inceptisols covering areas of Varanasi, Chandauli, Sant Rabidas Nagar, Jaunpur, Ghazipur, Mirzapur and Sonbhadra districts of Uttar Pradesh having a mean annual rainfall of 1080 mm.*	Ridge-furrow planting of Pigeonpea + rice (2:4) in upland and medium lands Okra + pigeonpea Tomato + linseed/lentil Maize (fodder)/ cowpea – oats Pearlmillet + cowpea – oats Boundary Plantation – D. sissoo, Eucalyptus Live fence – Outer layer: Lawsonia sp Inner layer : Leucaena, Moringa Trees on crop lands – Fodder/green biomass : Leucaena Fruit : Amla, Ber, Mango, Bael Wood (Commercial/farm use/fuel wood) : Eucalyptus Medicinal and aromatic plants : Vetivera Livestock : Cattle, Buffaloes, Sheep, Goat, Poultry
Rice - Ranchi AESR. 12.3. Red light textured soils with 1500 mm	*Sub-Humid Alfisols covering entire plateau of Jharkhand state, parts of Rohtas, Gay, Jamui in Monghyr district, Banka sub-division of Bhagalpur district in Bhir and Purulia and Bankura districts of West Bengal having a total annual rainfall between 900-1500 mm.*	Rice + pigeonpea (3:1) and groundnut + pigeonpea (2:1) in uplands Agri horticulture: Fruit crops (Nungo /citrus /sapota /pomegranate /custard apple /litchi/jack fruit jamun) +field crops (pulses/oilseeds) Alley cropping: Leucaena + turmeric/ginger Boundary Plantation – Eucalyptus Live fence – Outer layer: Lawsonia Inner layer : Leuceana, Tectonia grandis Trees on crop lands – Fodder/green biomass : Leucaena Fruit : Mango, Ber Wood (Commercial/farm use/fuel wood) : Tectona grandis, Eucalyptus Medicinal and aromatic plants : Vetivera, Palmrosa Livestock : Cattle, Buffaloes, Sheep, Poultry, Duckery, Piggery
Fingermillet - Bangalore AESR. 8.2. Semi arid deep alfisols with 607 mm	*kharif semi-arid deep alfisols with 6.07 mm rainfall domain for central, eastern, and southern agro climatic zones of Karnataka covering Davanageri, Chikmagalur, Hassan, Mysore, Chamaryanagar, Chitradurga, Tumkur, Kolar, Bangalore (rural and urban) and Mandya districts.*	Alternate Farming systems- Piggery/Sheep rearing/ poultry Boundary farming- Glyricidia (on bunds) Fodder system- Bajra/Maize /Sorghum/ Fingermillet+Pigeonpea
Maize - Ballowal Saunkhri AESR. 9.1. Semi arid inceptisols with 1000 mm	*Semi Arid Inceptisols covering Kandi areas of Punjab having annual rainfall of 1000 mm.*	Agrifodder system- Pearl millet + cluster bean (fodder) Agrihorticulture- Guava : Groundnut/ black gram/ cluster bean (fodder)/Wheat/ barley/ lentil Peach : Groundnut/ sesame/ black gram/Wheat/ barley/ taramira Aromaculture- Lemon grass

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Table.2. Suggested Farming Systems for wastelands in different Agro Climatic Zones

(a) Degraded Pastures and Barren Rocky area

Agro climatic region	Gullied Ravinous land				Land with/without Scrub			
	Area Sq.km	Existing system	Potential Farming Systems	Economics (Rs/ha)	Area (Sq. km)	Existing System	Potential Farming Systems	Economics (Rs/ha)
1. Western Himalayan zone	69	Pasture lands with low carrying capacity	Silvipasture with trees like Acacia catechu, Grewia optiva	2000-4000	3566	Degraded pastures	Hortipasture systems with Peech, plum and apiary	6000-7000
2. Eastern Himalayan zone	0	-	-	-	6990		Hortipasture systems with mandarin	3000-4000
3. Lower Gangetic plain	102		Silvipasture with Acacia mangium, Gmelina arborea	2500-3500	746		Hortipasture with species like mango, jack, jamun	2500-4000
4. Middle Gangetic plain	235		Silvipasture with Acacia auriculiformis & Erythrina indica	3000-3500	2817		Horti pasture with sps like litchi, Mango	4000-4500
5. Upper Gangetic plain	1262		Silvipasture with Dalbergia sissoo, Leucaena	2500-3000	1860		Horti pasture with sps like guava, jamun, ber. Poplar based systems	3000-4000
6. Trans Gangetic plain	218		Silvipasture with Dalbergia sissoo, Leucaena, Acacia	2500-3000	1328		Poplar based systems. Horti pasture with sps like guava, jamun, ber.	2500-4000
7. Eastern plateau & hill region	1414		Silvipasture with trees like leucaena and albizia sps., Cymbophogon sps, Vetiver	3000-5000	24572		Horti pasture with sps like Mango, sapota, Pome granate.	4000-5500

8. Central Plateau & hills	9897		Silvipasture with trees like Acacia sps and albizia sps., Cymbophogon sps, Vetiver	3000-5000	31309		Agri horti systems like Mango, Pomegranate, Sapota , Medicinal plants like Safed musli, Gymnema, Gloriosa, Ashwagandha	3500-4500
9. Western Plateau & hills	3291		Silvipasture with trees Acacia, Neem, aromatics like palmarosa. Medicinal like Catharanthus.	4000-5200	29439		Horti pasture with trees like tamarind, Pome granate, Guava Medicinals like Ashwagandha, Aloe vera, Asparagus.	4000-5400
10.Southern Plateau & hills	709		Silvipasture with trees like, Neem, leucaena, Hardwickia, aromatics like palmarosa	3500-4700	18460		Horticulture based systems (tamarind, mango, sweet orange, pome granate etc.) aloe vera, Henna, Curry leaf	3600-5200
11. East coast plains & hills	635		Silvipasture with trees like, Dalbergia sissoo, Acacia mangium	2000-3000	14145		Horti pasture systems with species like tamarind, sapota	3000-4000
12. Western plains & ghat region	0	-	-	-	6228		Coconut based multitier systems	2500-3500-
13. Gujarat plain & hill region	499		Silvipasture with trees like Acaccia, Hardwickia, palmarosa, Henna, Senna	3500-5000	8513		Horti pasture like ber jamun, pomegranate, fig, Henna, Medicinals like senna, Aloe vera, Gymnema, Ashwagandha,	4000-5000