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Land use planning for low rainfall (450-750 mm) regions of India

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Abstract: Land use planning is the systematic assessment of physical, social and economic factors in such a way as to encourage and assist land users in selecting land use options. This is an interactive and continuous process of development, to assess the future potential of the agriculture and allied sectors in order to achieve accelerated growth and productivity through judicious management of land and water resources and maintain a sound ecological balance together with optimal fulfilment of human demands, land use and land management have to be well-adapted to the land resources and to the ecological conditions. Increasing pressure on land means that planning decisions ought to be made only after a comprehensive analysis of all relevant factors. In India, low rainfall regions (450-750 mm) suffer from a number of biophysical and socio-economic constraints which affect productivity of crops and livestock, therefore the farmer in low rainfall regions *i.e.* arid and semi-arid areas has established traditional land use with multiple/mixed crops and crop-livestock farming systems to cope with the risks associated with drought, market prices *etc.* The various strategies employed to achieve the best land-use options are minimal or reducing land degradation; efficient soil health management strategies such as (cover crops, crop residue management, integrated nutrient management, tank silt application); conservation agriculture strategies; rainwater management; higher land productivity with efficient crops and cropping systems; alternative land use systems; integrated farming systems; efficient farm mechanization and agro-advisories. The goal of the new integrated approach to planning the use and management of land resources is to make optimal and informed choices on the future uses of the land. Finally, for efficient land use planning, long-term planning (over a 50 year horizon) is necessary for sustainable land use in both rural and urban areas, backed by ten year periodic action plans.

Key words: *Land use planning, arid and semi arid regions, soil and water management, farming systems, alternate land use*

Introduction

Ever since its independence in 1947, India's agriculture growth has moved the country from severe food crisis to aggregate food surplus and, rainfed agriculture has played an important role in this. Rainfed lands account for two-third of total net sown area, with 48 % area under food crops and 68 % under non-food crops. One of the major challenges facing rainfed agriculture in India today is its sustainable development, through conserving and enhancing the inherent capacity of its land and other natural resources to sustain it. Therefore it is necessary to constantly address this concern. Along with increasing production of food grains and other agricultural products, it is necessary to enhance and conserve the stock of available land, water and other natural resources and develop improved technologies, which maintain and improve the productive capacity of natural resources (Singh and Rathore 2010).

The current land use practices comprise of monocropping, mixed/intercropping and farming systems (with annuals, perennials and small/large ruminants) which are no doubt supporting resource poor farmers by exploitation of natural resources, particularly land resources, but neither the productivity levels, viable incomes, year round employment or the sustenance of the ecosystem are taken care of adequately. Added to this, land degradation and impending impacts of climate change/variability on agriculture are the twin problems challenging the agriculture in the low rainfall regions. Kinds, degree and extent of land degradation are of immediate concern in sustaining production system, reducing cost of production, and natural resource management and conservation. In these complexities, all the existing traditional land uses cannot provide sustainable models. The final aim of any land use planning in the low rainfall regions is to build land use models for resource farmer that sustain the farming system, give staggered and attractive income, improve the land quality and feed to the livestock.

Land Use Planning is an interactive and continuous process of development, requires flexibility, does not have a clear end-product, is problem oriented, is area specific and involves all stakeholders (FAO 1993). The National Agricultural Policy (2001) emphasized on the production of technically sound, economically viable, environmentally non-degradable and socially acceptable use of natural resources (land, water and genetic environment), use of wastelands for agricultural and afforestation, drought proofing of rainfed agriculture, improving the quality of soil and land resources, development of rainfed horticulture and other food supplying export oriented employment, generating alternate land use systems in rural areas and feed and fodder security for animals through cultivation of fodder crops/trees.

Land use planning vis-a-vis enhancing land productiv ity

Land productivity is determined by a plethora of factors particularly in low rainfall regions which are inherently plagued with low and erratic rainfall, poor land/soil quality, low crop productivity and income levels, all of these influence the food security and livelihood of the farmers in these regions. The concerted efforts and strategies are thus needed for addressing these issues wherein land use planning with effective land resource management strategies have a greater role to play. The LUP assesses the production potentials of various agro-ecologies at sustainable levels and matches them with the market forces. The strength of LUP is in prioritizing all land use (in a zero-base budgeting context) according to its capability coupled with the renewable water resources availability. Besides the cropland, it includes assessment of suitable production capacities of forests and other land-based activities such as animal husbandry and inland and coast fisheries sectors.

India is constrained by low or stagnant crop yields, land tenure insecurity, small size and fragmentation of landholdings, land degradation and lack of farmer's participation in decision making processes. Therefore, positive measures and policies for improving land utilization systems to enhance productivity and conserve their land resources is utmost priority. Scientists of dryland have developed many alternate land use systems which may suit different agro ecological situations to study the potential of land productivity enhancement through better land management and land use planning in the country. Assessment of better land management is evaluated in relation to farm practices. These are alley cropping, agri-horticultural system and silvi-pastoral systems that utilize the resources in better way for increased and stabilized production from drylands. The low rainfall regions (450-750 mm) are characterized with diverse biophysical (land, soil, water) and socio-economic settings. Some of these regions in India are shown in figure 1 which comprise of northern plains, central highlands including Aravallis, Deccan plateau, Tamil Nadu uplands and south Tamil Nadu plains.

The low rainfall regions suffer from a number of biophysical and socio-economic constraints which affect productivity of crops and livestock. These include low and erratic rainfall, droughts, land degradation and poor productivity (Abrol and Katyal 1994), low level of input use and technology adoption, inadequate fodder availability and low productive livestock (Singh *et al.* 1997).

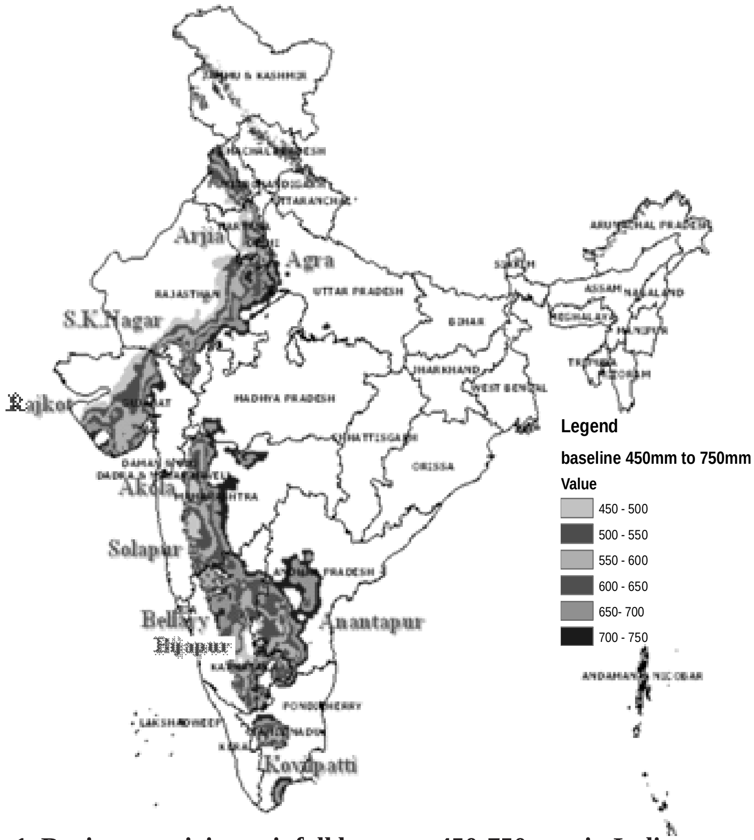

Fig.1. Regions receiving rainfall between 450-750 mm in India

Agro-ecological and socio-economic settings of low rainfall regions (450-750 mm)

Rainfall variability

In low rainfall regions, rainfall is the main source of water for raising crops and the major constraint is the tremendous variability in rainfall from year to year and season to season (Victor *et al.* 1994) causing uncertainties in crop production. The major water-related challenge for rainfed agriculture in semi-arid and dry subhumid regions is to deal with the extreme variability in rainfall, characterized by few rainfall events, high-intensity storms, and high frequency of dry spells and droughts. The rainfall pattern has become increasingly erratic over the past couple of decades and the farming community is finding it more difficult to tailor their cropping cycles to this changing pattern.

Land use pattern

Land use systems have both spatial and temporal dimensions. These must be understood if one endeavors to describe, classify, survey or study land use systems at the level of spatial aggregation required for solving specific natural resources management problems (De Bie 2002). The land use pattern in low rainfall regions is shown in Table 1 and net rainfed area in low rainfall regions is 17.47 m ha covering 54.6% of net cultivated area in the region.

Table 1. Land use in area receiving 450-750 mm rainfall

Particulars	Area (m ha)	Percentage (%)
• Forest area	5.65	10.35
• Area under non agricultural uses	3.87	7.10
• Barren uncultivable land	3.89	7.13
• Permanent pastures	2.36	4.32
• Land under miscellaneous crop not included in net area	0.20	0.37
• Cultivable waste land	1.61	2.96
• Fallow lands other than current fallow	2.14	3.92
• Current fallow	3.54	6.48
• Net area sown	31.33	57.38

Land degradation/wasteland scenario

Land degradation, which is more pronounced in rainfed regions, is a major threat to food and environmental security. This area is generally subject to wind and water erosion and is in different stages of degradation. The problems of land degradation are prevalent in many forms throughout the country (Table 2). About 120.72 m ha of land in the country of land in the country is degraded due to soil erosion and about 8.2 m ha due to soil erosion and water logging problems. Besides, huge quantity of nutrients are lost during crop production cycle which is further aggravated by imbalanced application of nutrients, excess mining of micronutrients leading to deterioration of land and soil quality (ICAR Vision 2030).

Table 2. Degraded and wastelands of India (million ha)

Degradation type	Arable land (M ha)	Open forest (<40% canopy) (M ha)	Data source
• Water erosion (>10 tons/ha/yr)	73.27	9.30	Soil loss map of India, CSWCRT & TI
• Wind erosion (Aeolian)	12.40	-	
Sub total	85.67	9.30	Wind erosion map, CAZRI
Chemical degradation			
• Exclusively salt affected soils	5.44	-	National salt affected map, CSSRI, NBSS & LUP, NRSC and others
• Salt affected and water eroded soils	1.20	0.10	
• Exclusively acidic soils (pH<5.5)	5.09	-	Acid soil map of India NBSS&LUP
• Acidic (pH<5.5) and water eroded soils	5.72	7.13	
Sub total	17.45	7.13	
Physical degradation			
• Mining and industrial waste	0.19		Waste land map of the NRSA
• Water logging (permanent surface inundation)	0.88		
Sub total	1.07		
Total	104.19	16.53	
Grand total (Arable land and open forest)	120.72		

Source: NAAS 2010.

The first predominant cause of land degradation in rainfed regions undoubtedly is water erosion. The second major indirect cause of degradation is loss of organic matter by virtue of temperature mediated fast decomposition owing to high temperature prevailing in these regions (Srinivasarao *et al*. 2009 a, b). Regular additions of organics without hastening their decomposition process can provide some relief (Srinivasarao *et al.* 2011 a,b).

Soils

Climate and soil health are interrelated though the factors such as management practices which also influence the soil health. Disproportion in the annual distribution of rainfall and excessive heat effect contribute to maintenance of soil health. Agricultural production of the country largely depends upon its soil and climate. Both the soils type and cropping patterns vary within the 450-750mm rainfall zones across the country. Examples of some locations from the low rainfall regions which are also under the network of All India Coordinated Research Project for Dryland Agriculture (AICRPDA) which fall in this low rainfall zone are given in Table 3.

Table 3. Soil types and mean annual rainfall of various AICRPDA centers located in low rainfall regions

Locations	Mean Annual Rainfall (mm)	Soil type	LGP	Crops/Systems
Agra	665	Alluvial-deep Inceptisols	90-120	Pearlmillet, Mustard, Pearl millet + sesame (Strip cropping)
Anantapur	590	Red-shallow Alfisols	90-120	Groundnut, Castor
Akola	750	Black-medium deep Vertic/ Vertisols	120-150	Cotton/Soybean/Sorghum Cotton + greengram; Pigeonpea
Arjia	656	Black-shallow deep/ medium deep Vertisols/ Vertic Inceptisols	90-120	Maize /Blackgram /Sesame /Sorghum/Groundnut Maize + blackgram/Groundnut + sesame
Bellary	500	Black-deep Vertisols	90-120	Sorghum-Chickpea
Bijapur	680	Black-medium deep/ deep Vertisols	90-120	Rabi Sorghum, Legumes, Chickpea, Oil seed crops
Rajkot	615	Black-deep Vertisols/ Vertic Inceptisols	60-90	Groundnut/Castor/Sesame Groundnut + castor /Groundnut + sesame
Kovilpatti	743	Black-deep Vertisols	90-120	Blackgram/Greengram/Pearlmillet/Cotton/Maize
S.K.Nagar	550	Desert-deep Aridisols	60-90	Pearlmillet, Castor, Clusterbean
Solapur	723	Black-medium deep Vertic/ Vertisols	90-120	Pearlmillet/Sunflower/Rabi Sorghum/Chickpea

LGP: Length of growing period in days; *Source*: Vittal *et al.* 2003a; Srinivasarao *et al.* 2013a.

Operational holdings

Land cultivated by a household provides a close approximation to the size of operational holding of the household. Conceptually, data on land owned correspond to ownership holding of land, and data on land possessed correspond to operational holding of land. The size of the land holding (operational) vary *i.e.* marginal holdings comprise of 11.4% and small holdings comprising of 20.4% of the total operational holdings in the low rainfall regions.

Yield gaps

Yield gaps are quite prominent in drylands. Yield gaps are low in irrigated agriculture (<20%) but significantly high in rainfed agriculture (>50%) (Lobell *et al.* 2009). The yield gap exists because of complex biophysical, management and socio-economic factors. The yield gaps *i.e.* yield gap I (Potential experimental yield- Attainable yield in farmers field with improved technology) and yield gap II (Attainable yield in farmers field with improved technology-Farmers yield) for the major rainfed crops across low rainfall regions are high (Table 4). For example, yield gap I in the pearlmillet crop is ranged from 299 to 900 kg ha^{-1} and yield gap II ranged from 300 to 1600 kg ha^{-1}. These yield gaps have to be bridged through location specific double rainfed technologies.

Table 4. Major crops and yield gaps in rainfed regions of India

AICRPDA Centre & Crops	Yield gaps			Yield gap-I (kg/ha)	Yield gap-II (kg/ha)
	Y_1	Y_2	Y_3	(Y_1-Y_2)	(Y_2-Y_3)
Akola					
Cotton	1200	1115	857	85	258
Soybean	2500	1215	1095	1285	120
Arjia					
Maize	4325	3513	2117	812	1396
Sesame	699	430	230	269	200
Groundnut	1500	1258	850	242	408
Agra					
Pearlmillet	3565	3266	2311	299	955
Mustard	2105	1810	1480	295	330
Bijapur					
Pearlmillet	2000	1500	1200	500	300
Sorghum	4500	2500	1300	2000	1200
Chickpea	2500	2000	1300	500	700
Kovilpatti					
Bt cotton	3000	2500	2000	500	500
Sorghum	4000	3000	1800	1000	1200
Maize	5500	3500	2800	2000	700
Blackgram	1400	1200	800	200	400
Greengram	1500	1200	800	300	400
Rajkot					
Groundnut	3500	1157	1076	2343	81
Cotton	3500	3260	3125	240	135
SK Nagar					
Pearlmillet	2100	1200	800	900	400
Castor	3500	1800	1500	1700	400
Cotton	1800	1500	700	300	800
Solapur					
Pearlmillet	4500	3800	2200	700	1600
Rabi sorghum	3500	2200	1600	1300	600
Chickpea	2000	1500	1000	500	500

Y_1: Potential experimental yield (kg/ha); Y_2: Attainable yield in farmers yield with improved technology (kg/ha); Y_3: Farmers yield (kg/ha)

In the state of Andhra Pradesh, cotton yields in Khammam district from the 15 farmers' fields indicated that yield gaps were higher between farmers practice (FP) and site specific nutrient management (SSNM) have widened at higher productivity levels as compared to lower yield levels (Fig.2). In Nalgonda district, the yield gap between FP and SSNM were much wider at high productivity levels in groundnut and greengram (Srinivasarao, 2012a).

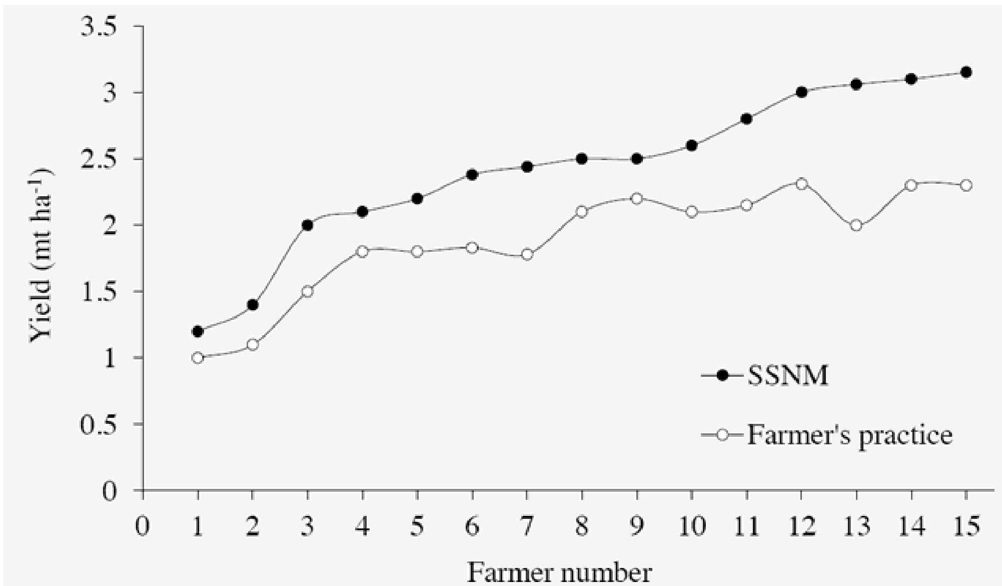

Fig. 2. Effects of balanced fertilization on Bt-cotton yield in farmers' fields of T. Cheruvu cluster, Khammam district, AP, Kharif 2009-2010. (BN=SSNM; FP=Farmers' practice only NP) (CD=0.23, *p*=0.05)
(Source: Srinivasarao *et al.* 2012a)

Strategies for efficient land use planning in low rainfall regions

Land-use planning is the systematic assessment of land and water potential, alternatives for land use and economic and social conditions in order to select and adopt the best land-use options. The various strategies to achieve the best land-use options are discussed below.

Technological interventions

Minimal or reducing land degradation

The rainfed areas in India are characterized by very low and erratic rainfall, frequent droughts; and agricultural production is uncertain and risky on the degraded soils and depleted water resource. Due to these adverse conditions, agricultural productivity and farmers' incomes are low and highly variable. The most serious threat to our food and environmental security is land degradation. In India, degradation is one of the major soil health issues accounting for 120.72 m ha, of which 73.3 m ha is affected by water erosion, 12.4 m ha by wind erosion, 6.64 m ha by salinity and alkalinity and 5.7 m ha by soil acidity. Management practices such as application of organic manures (composts, FYM, vermicomposts), legume crop based green manuring, tree-leaf based green manuring, crop residue recycling, inclusion of legumes in crop rotation need to be encouraged (Srinivasarao *et al.* 2011 a, b) in order to minimize soil degradation. High intense rainfall events in black soils have recurrent in the recent fast, causing loss of fertile top soil and nutrients. To minimize these losses, plans need to be prepared for such events before and during is necessary. Land configuration with ridge and furrow system, broad bed and furrow etc. provide draining out, excess water from crop fields and minimize soil and nutrient losses.

The problem of soil salinity (chemically degraded soils) is of major concern particularly for arid to semi-arid areas. In saline soil the available moisture range is low and crop has to spend more energy to extract water from the soil because of high osmotic potential of the soil solution. These also adversely affect water and nutrient availability and induce micronutrients deficiency. Insufficient rainfall together with high evaporative demand and shallow ground water in most locations enhances the upward movement of salts to the soil surface. The efforts should be made to minimize further degradation of crops, amelioration with cost effective management practices. Any practices that will increase water use in the recharge areas or in other ways decrease the excess water which ultimately contributes to seepage will help in the control of saline soils. The land use planning in salt affected lands should take care of those practices that can minimize salinization by growing deep rooted perennials, selection of salt-tolerant crops and varieties and use of extra water for leaching.

Covering the land with cover crops such as legumes will help in protecting the land during high intense rainfall events, and ill effects of extreme temperatures during summer reduction in evaporation, enhanced biological activity due to congenial soil habitat conditions, higher C sequestration *etc*. Hence, this concept needs to be propagated extensively among the farming community. For example, in low rainfall regions horsegram is sown late in the rainy season by resource-poor farmers in marginal, drought-prone areas of India. As sowing and early crop growth coincides with declining rainfall, crop establishment is often poor and yields are low. Though horsegram is not an assured crop for grain production in the *rabi* season in a deficit rainfall year, it is an assured crop for biomass production. Studies have confirmed the possibility of on-farm generation of horsegram biomass by using off-season rainfall. In a 10-year experiment, production of 3.03-4.28 t ha^{-1} yr^{-1} of fresh biomass was reported (Venkateswarlu *et al.* 2007). Incorporation of this biomass for longer period results in improvement of soil organic carbon (SOC), microbial biomass and nutrient status and land quality in general

The problem of on-farm burning of crop residues has intensified in recent years due to shortage of human labour, high cost of removing the crop residues by conventional methods. Crop cover with recycling of crop residues is a pre-requisite and an integral part of conservation agriculture. However, sowing of a crop in presence of residues of preceding crop was a problem. But new variants of zero-till seed-cum-fertilizer drill/planters such as happy-seeder, turbo seeder, rotary-disc drill and easy seeder have since been developed to facilitate direct drilling of seeds in the presence of surface retained residues (both loose and anchored residues upto 10 tonnes ha^{-1}). The crop residues retained on surface help conserving moisture and nutrients and controlling weeds in addition to moderating soil temperature (NAAS 2012).

Due to limited production of biomass, competing uses of crop residues and shortage of firewood, farmers often find it hard to use crop residues to cover soil surface in dryland eco-systems. However, Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad showed that in dryland ecosystems, where only a single crop is grown in a year, it is possible to grow a second crop with residual soil moisture in the profile under conservation agriculture with soil covered by crop residues. However, it is, better to use the chopped biomass of semi-hard woody perennial plants instead of crop residues to cover the soil surface. The soil organic carbon (SOC) in most of rainfed production systems is declining due to complete removal or burning of crop residues. Many dryland crop residues particularly those of cotton, pigeonpea, castor, chilli and maize are burnt regularly. CRIDA introduced rotavator for incorporating the crop residues in the soil (Fig.3). Plant residues serve as effective source of plant nutrients and humus in soil. The soil organic matter (SOM) plays an important role in maintaining proper rhizosphere.

Fig.3. Burning of crop residues (a) and crop residue recycling in to soil through rotavator

Integrated nutrient management

Fertilizer recommendations for dryland crop production have been made primarily for N and P and to a lesser extent for other nutrients. A number of practical recommendations for fertilizers as well as INM for several soil-crop systems in rainfed have been compiled by Singh *et al.* (2000) and Faroda (1998) based on research carried out by AICRPDA. These include the integrated use of fertilizers, green leaf manures and bio fertilizers. Site specific nutrient management (SSNM) approach which was implemented in several farmers' fields based on participatory soil sampling and development of soil health cards. Based on the soil test data and crops grown in each field, SSNM sheet was developed in each farmer's field. SSNM sheet developed for groundnut and greengram in light textured red soils at Dupahad cluster of Nalgonda, Andhra Pradesh is presented in Table 5, where deficient nutrients are included in nutrient recommendations instead of blanket application. With this, farmer invested only on deficient nutrients and omitted nutrient application which was in sufficient range in soils. Thus, input cost reduced and nutrient use efficiency improved considerably (Srinivasarao *et al.* 2012b). Various benefits of SSNM practice include lowering input cost, higher nutrient use efficiency, and higher water use efficiency.

Table 5. Farmer field specific fertilizer recommendation developed for oilseed/pulse crop based on soil test value for Dupahad cluster of Nalgonda district, A.P.

Village	Crop	Fertilizer requirement				
		Urea	DAP	MoP	Gypsum	$ZnSO_4$
Jalmakunta tanda	Groundnut	-	125	90	-	50
	Greengram	50	-	90	-	-
	Greengram	50	-	-	-	25
	Greengram	-	125	90	150	50
	Greengram	50	-	-	-	50
	Greengram	-	125	-	-	50
	Greengram	-	125	90	-	50
	Greengram	50	-	65	-	50
	Greengram	-	125	90	150	50
	Greengram	-	125	65	150	50
	Greengram	-	125	65	150	50
	Greengram	-	125	65	-	25
	Greengram	50	-	65	-	50
	Greengram	50	-	90	-	50
	Greengram	-	125	90	-	50
	Greengram	50	-	65	-	25
New banjarahills	Greengram	-	125	65	150	50
	Greengram	50	-	65	150	50
Peddagarakunta tanda	Greengram	50	-	90	150	50
Seetamma tanda	Groundnut	50	-	90	-	50

Source: Srinivasarao *et al.* 2010.

In the soils of rainfed areas in India, the negative balance of nitrogen and phosphorus (Rego *et al.* 2003) and recently wide spread deficiency of zinc was reported (Sahrawat *et al.* 2007). Long term study conducted in Alfisols under groundnut monocropping at Ananthapur under rainfed conditions in southern India indicated higher magnitude of depletion of zinc (0.52 mg kg^{-1}), whereas soils under treatments based on input of FYM exhibited relatively higher status of available Zn (0.70 mg kg^{-1}) (Srinivasarao *et al.* 2013b).

Tank silt application

Silt is a combination of sand and clay particles collected from tanks or lakes in the villages. Silt can also be referred to as eroded soil deposited in the tanks and lakes of the villages and in delta areas. It is mainly applied to improve soil and moisture conservation, enhancement of water holding capacity as well as increase aeration, porosity and nutrient status of the soil for a good crop growth. Community tanks have been an integral part of rural areas for centuries. Tank silt possesses high water retention capacity and also acts as a good source of nutrients. Analysis of several tanks in Warangal, Anantapur and Nalgonda districts of Andhra Pradesh showed the potential of tank silt in supplying organic carbon and several nutrients. It is particularly beneficial in light textured soils. Desilting of tanks in Warangal indicated the presence of all the valuable nutrients required for plant growth in adequate quantities. Recycling of tank silt will overcome the deficiency of nutrients particularly that of zinc, boron and sulphur observed in many soils. It can also improve SOC content of soil resulting in improved soil health with quantified tank silt application, the lands in arid and semi arid regions can be made more productive and care. The tank beds also can be used for community fodder banks thus helping supplying fodder in village.

Conservation agriculture strategies for carbon sequestration and sustain agriculture production

Conservation agriculture (CA) has emerged as an alternative strategy to sustain agricultural production due to growing resource degradation problems, particularly under rainfed conditions. CA practices also reduce the carbon emissions by way of reducing the tillage intensity and contribute to carbon sequestration. Available information indicates that CA practices contribute towards saving in energy, reducing cost of production and contributing substantially towards profitability. There is a need to integrate land configuration methods such as ridge and furrow, conservation furrow in CA systems to develop a comprehensive package of practices to address all issues for diverse rainfed production systems. Involving AICRPDA network and CRIDA in this initiative would help development of location specific conservation agricultural practices for various rainfed production systems, wherein the proven conservation practices, subsequently be demonstrated through the line departments in a short time.

Rainwater management (in-situ and ex-situ) for higher water productivity

In the arid lands, the rainfall being low, the main strategy of rainwater management is through efficient dry farming practices. However, sometimes in the arid lands also considerable run off occurs. This is how droughts and floods are common phenomena in many of these regions. Therefore, in these arid zones there are some possibilities for increasing the efficiency of rainwater management for increasing the higher land and water productivity. The harvested rainwater should be used only for “life saving” irrigation at the most critical stages of crop growth or for extending the cropping season, thus making inter-or sequential cropping possible. Integrated watershed management is the key to conservation and efficient utilization of natural resources of soil and water, particularly in rainfed agriculture where water is the foremost limiting factor of crop productivity.

Land treatment/configuration

Impact of various land treatments across rainfall zones and soil types in the network of AICRPDA was assessed in terms of runoff and soil loss, land degradation, moisture conservation and farm productivity and economic benefits (Table 6). These land treatments provided opportunity to conserve moisture *in situ* and improved profile moisture storage, and key adaptation strategies to mitigate water stress under intermittent droughts. Various land treatments in alluvial soils of Hisar (Haryana), broad bed furrow in southern medium deep black soils of Kovilpatti (Tamil Nadu) and conservation furrow in red soil regions of Andhra Pradesh and Karnataka provide resilience to droughts and mid season droughts.

Table 6. Land treatment across rainfall zones, soil types to conserve moisture *in situ*

Practice	Target Area	Benefit (Rs/ha)
Broad bed furrow/ ridge furrow planting	Vertisols, Malwa region	3000-5000
Conservation furrow	Southern plateau Alfisols	800 -1000
Ridge and furrow planting of upland rice + pigeonpea	Inceptisols, Eastern U.P/ Vindyan plateau region	2500-3000
Compartmental bunding	Vertisols North Karnataka region	1500-2000
Ridge and furrow	Sandy soils of Haryana, Vertisols of Maharashtra, eastern Rajasthan etc.	1000-1500

Detailed soil conservation measures to be carried out by farmer/community based land capability and rainfall are presented in Table 7.

Table 7. The prioritized land capability and rainfall based soil and water conservation measures

Rainfall <500mm		Rainfall 500-750 mm	
LCC I	LCC II	LCC I	LCC II
Conservation furrows Mulching Ridging Sowing across slope Tied ridges Tillage	Contour farming Conservation furrows Mulching Ridging Sowing across slope Tied ridges Tillage	Conservation furrows Mulching Ridging Sowing across slope Tied ridges Tillage	Contour farming Conservation furrows Mulching Ridging Sowing across slope Tied ridges Tillage
BBF Inter row system Small basins	BBF Contour strip farming Inter row system Small basins	BBF Inter row system Small basins	BBF Contour furrows/strip tillages Lock and spill drains Runoff strips Small basins
Contour bunds Field bunds Khadin	Contour bunds Field bunds Khadin Interplot water harvesting	Contour bunds Field bunds Khadin	Contour bunds Field bunds Khadin Zingg terracing

Source: (Vittal *et al.* 2003b); LCC- Land capability class

In-situ moisture conservation practices

Various *in situ* moisture conservation practices such as summer tillage for alluvial, red and other light soil not only conserves soil moisture but also reduce the weed growth for next season compartmental bunding in heavy black soils conserve sufficient moisture for assured *rabi* crops cultivation across the slope helps in retaining in rain water in soil itself and conservation furrow retain additional soil moisture compared to farmers' practice resulting in better growth and higher yield. Soil and water conservation practices such as compartmental bunding, terracing, contour tillage and ridge and furrow can be used to increase surface storage, reduce slope gradient and conduct water from field at non-erosive velocity. However, impact of these conservation measures varies with the soil type, agroclimatic condition and their effectiveness cannot be generalized (Table 8) (Vittal *et al.* 2002).

Table 8. Influence of soil and water conservation measures on crops at different locations

Crop	Location/State /Climate	Soil	Treatment	Yield (kg/ha)	SI
Pearl millet	Agra/ Semiarid	Inceptisols	Nutritious cereals		
			Raised bunds (20 cm high) with rectangular belts (6 x 2.7m) across slope	2193	0.67
			Compartmental bunding (3 x 4.5m)	2153	0.66
			Farmers' method (control)	1845	0.46
Pearl millet	Dantiwada/ Gujarat/ Semi-arid	Aridisols	Compartmental bunding (3 x 4.5m)	1132	0.67
			Flat sowing and ridges at 3 m distance	986	0.57
			Farmers' method (control)	819	0.46
Castor	Dantiwala/ Gujarat/ Semi-arid	Aridisols	Ridges and furrows	1668	0.40
			Flat beds	1598	0.38
			Trench (control)	1412	0.30

Source: Vittal *et al.* 2002.

Water nutrient interactions

Water and nutrients are two most critical factors in crop production. Optimum combination of water and nutrients are essential for enhancing their use efficiencies and maximizing crop yields. In dryland conditions, the efficient use of nutrients such as nitrogen varies at different sites mainly because of differences in plant available water. In addition to nitrogen, plant available water *viz.,* available water stored in the soil profile at seeding plus effective rainfall during the growing season determines the yields of dryland crops. The variable effects of components of water supply on crop yields are probably related to the level of N availability and its use by crops. This implies that efficient fertilizer use by the crop is critical through appropriate partitioning of water supply into its components *viz.,* available soil water and seasonal rainfall.

Higher land productivity with efficient crops and cropping systems management strategies

Drought tolerant crop cultivars

Increasing temperatures and less and more erratic rainfall will exacerbate conflicts over water allocation and the already critical state of water availability (Thomas 2008). For dryland agriculture in order to successfully adapt to mid season drought in low rainfall regions there is need to identify drought tolerant crops and cultivars for diverse agro ecology (climate and soil type).

The drought tolerant crops suitable for low rainfall regions are fingermillet, sorghum, horsegram, sesame, mothbean, clusterbean, castor cotton and lentil *etc*. The performance of pearlmillet and fingermillet was better during late season drought where as pulses performed better during early season drought. Some of the proven short duration drought tolerant varieties of dominant rainfed crops and rain water use efficiency (RWUE) of varieties in low rainfall regions (450-750 mm) are given in Table 9. In Hisar, pearlmillet showed the highest RWUE (8.0) in *kharif*.

Table 9. Short duration drought tolerant varieties of dominant rainfed crops in low rainfall regions

AICRPDA Center	Predominant rainfed crop	Improved/drought tolerant variety	RWUE (kg/ha-mm)
Arjia	Horsegram	HG-2	2.77
		HG-5	1.15
	Sesame (AVT)	AVT-09-20	3.07
Hisar (Kharif crops)	Pearlmillet	HHB-197	8.0
		HC-10	6.2
	Clusterbean	HG2-20	3.5
		HGS-870	2.6
	Mothbean	RMO-225	3.6
		HM-61	2.5
	Castor	DCH-32	1.7
		CH1	0.8
Akola	Cotton	AKA-8	3.57
		B.N. bt	1.91
	Castor	GCH-5	2.13
		GCH-6	1.05
SK Nagar	Castor	GCH-7	-
Rajkot	Groundnut	JVR-497	4.01
		M-335	1.68
	Sorghum	SR-1904	30.2
		GJ-39	18.7

Source: AICRPDA, Annual Reports, 2008-2011

Integrated genetic and natural resource management (IGNRM)

Integrated genetic and natural resource management (IGNRM) was adopted to enhance agricultural productivity in rain-fed areas, which is a powerful integrative strategy of enhancing agricultural productivity. Watershed based research was an example of interdisciplinary research even before the term assumed significance (Shambu Prasad *et al.* 2005; 2006). The consortium adopted IGNRM approach for community watershed management and most interventions were for enhancing productivity and generating additional income for the small, marginal farmers and other vulnerable groups including landless and women to ensure tangible economic benefits. IGNRM focuses on key livelihood and income opportunities to improve the well-being of the poor with equity, multi-disciplinary, sustainability and community participation as core principles.

Grain legumes constitute an important component of drought prone agriculture with more than 85 % moisture after harvest of *kharif* crops in India (Reddy *et al.* 2007). An integrated study conducted in Arjia with

HIM-129 maize variety + 100% RDF + ridging after sowing gave an yield of 4870 kg ha^{-1} and RWUE of 7.13 kg/ha-mm. In a study on evaluation of drought tolerance of chickpea genotypes significant differences exhibited amongst the genotypes for phenology, vegetative growth and source, generative growth and sink capacity, physiological parameters and drought characteristics under moisture stress and non-stress conditions. The genotypes, Phule G 09103, Phule G 2008-74, Digvijay, Phule G 0302-26 recorded minimum percent reduction in yield due to moisture stress. Relative Leaf Water Content (RLWC), membrane injury index, chlorophyll content, chlorophyll stability index, proline accumulation and nitrate reductase activity were found to be the most useful parameters while selecting genotypes for drought tolerance. The genotypes Phule G 09103, Phule G 2008-74, Digvijay exhibited higher values for drought tolerance efficiency, proline content, chlorophyll content and lower values for drought susceptibility index, membrane injury index indicating their drought tolerance behaviour. Therefore, these genotypes can be used as sources of drought tolerance in further breeding programme for evolving the drought tolerant genotypes in chickpea (Ulemale *et al.* 2013).

Efficient cropping systems

In semiarid India, a large area is left fallow during the rainy season and cropped during post-rainy season under store soil moisture. The reasons for fallowing are different in low and high rainfall area. In areas of low (450-750 mm) and erratic rainfall, rainy season cropping is risky despite good moisture holding capacity of soil. Cropping systems differ according to climate and soil types. In the areas with 400 to 750 mm annual rainfall, mono cropping with traditional long duration crops is common. Cereals which have an adventitious root system mostly tap surface soil layer for water and plant nutrients. Under dry conditions roots of cereals can penetrate a little deeper in search of water. Legumes that have a tap root system absorb water and plant nutrients from surface as well as deeper soil layers. Generally adaptable crops are cereals, oil-seeds and pulses. For sustainability of intensive cropping systems, it is desirable not to grow a particular crop or a group of crops on the same soil for a long period. Pigeonpea grows extremely well as intercrop in drought conditions. Maize + chickpea (2:2), groundnut + sesame (2:1) soybean + pigeonpea (4:2), cotton + castor (2:1), cotton + greengram (1:1), fingermillet + groundnut (8:2), pearlmillet + pigeonpea (3:3) and pigeonpea+greengram (1:2) are some of the proven double intercropping systems in low rainfall regions (450-750 mm). Different intercropping systems yielded 25-30% higher yield compared to sole cropping (Venkateswarlu *et al.* 2012).

Contingency crop planning- Strategies for drought proofing and efficient agricultural land use

Contingency crop planning refers to making available a plan for providing alternate crop or cultivar choices and land, crop and crop management strategies in tune with the resource endowments of rainfall and soils in a given location. Contingency crop plan implementation is an adaptation strategy for sustainable land management to mitigate impacts of climate variability. The AICRPDA has been making efforts to develop and upscale appropriate contingency crop planning strategies to achieve sustainable productivity of rainfed crops in different agro-climatic environments. The project has also generated appropriate strategies/contingency plans and agro-techniques for growing rainfed crops to meet seasonal aberrations (normal and delayed onset, early withdrawal and extended monsoon conditions). Since *kharif* cropping is a primary activity in the rainfed areas of arid and semiarid lands, where monsoon variability plays a crucial role in production, contingency crop planning will require a greater attention in these areas. Long term strategic approaches are also needed to efficiently conserve and utilize rainwater on the one hand and in-season tactical approaches to mitigate the adverse effects of weather aberrations on the other (Joshi and Kar 2009).

Real time contingency planning was implemented under National Initiative on Climate Resilient Agriculture (NICRA) - AICRPDA in the regions receiving 450-750 mm rainfall. Under real time contingency planning, based on early, midseason or terminal drought situations the coping strategies adopted/demonstrated included were crop/soil/moisture management practices (change in crop/variety early, medium and late maturing), crop diversification, practices like change in seed rate, gap filling, thinning, life saving/supplemental irrigation nutrient management, interculture and weed management practices *etc.*). At S.K. Nagar, under early season drought, introduction of improved varieties/hybrids of pearlmillet, castor, greengram, clusterbean, mothbean and castor + greengram enhanced the yield with RWUE up to 1.33 kg/ha-mm and B:C ratio up to 7.42 and under delayed onset of monsoon, introduction of improved varieties of pearlmillet, clusterbean, castor, maize, greengram and blackgram resulting in yield increase up to 153.5 kg/ha; at Bijapur, improved varieties of chickpea (JG-11) performed better with increase in yield by 21% compared to local variety (305 kg/ha); at Akola, under midseason drought situation, introduction of improved variety of sorghum (CSH-14) and cotton + greengram (1:1), greengram + pigoenpea (4:2) and soybean + pigeonpea (4:2) systems with suitable varieties, *viz*., JS-335 (soybean, PKV-Tara (pigeonpea), Greengold (greengram) enhanced the yield up to 38% with B:C ratio of 2.45. At Kovilpatti, under excess rainfall situation during August, September, October and November and also during mid-season drought (during June, July to December), the improved varieties of cotton (RCH-530), maize (900 M Gold), greengram (CO-6), blackgram (normal), pearlmillet (80 M 32) and sunflower (CO-SFV)-5 performed better, resulting in higher yield and higher RWUE up to 13.49 kg/ha-mm (Srinivasarao *et al.* 2013a).

Alternate land use systems as higher land productivity and increase

Alternate land use systems such as tree farming, ley farming and dryland horticulture, other agroforestry systems including alley cropping, which are alternative to crop production are less risky, more stable and remunerative on marginal lands and are referred to as alternate land use. The sustainability of alternate land use systems (Table 10) varies with components of the systems, soil type and agro-climatic location and their effectiveness (Vittal *et al.* 2002)

Table 10. Performance of different tree species and crops for alternate land use at Arjia (Semi arid vertisols)

Alternate land use system	Yield (kg/ha)	Sustainability Index (SI)
Agroforestry		
I. Prosopis cineraria + Cenchrus setigerus	3483	0.61
II. Jatropa + green gram	63	0.57
I. Cenchrus setigerus (100%)	2670	0.58
II. Cenchrus setigerus (50%)	1813	0.55
I. Acacia tortilis (bunding and chiseling)	1716	0.94
II. Parkinsonia aculeate	1545	0.82

I and II are the top first rated treatments (Source: Vittal *et al.* 2002)

Land use planning with fodder systems for fodder security

According to Planning Commission, GOI, during 2002-03 the total fodder production in India was 88.08 thousand tons. In 2005, supply of green and dry fodder in India was 389.9 million tons and 443 million tons, respectively, whereas demand for green fodder was 1025 million tons and dry fodder was 569 million tons. Hence the green fodder deficit was by 61.961 % and dry fodder deficit was 22.081 %. Insufficient availability of fodder is thus one of the major constraints of livestock rearing in the country (Pushpa 2006). In India, there is no practice of fodder production in rural areas and animals generally graze naturally grown grasses and shrubs which are of low quality in terms of protein and available energy, they are thus heavily dependent on seasonal variations and this results in fluctuation in fodder supply round the year affecting supply of milk round the year. There is tremendous pressure of livestock on available feed and fodder, as land available for fodder production has been decreasing, as many rural livestock keepers are small and marginal farmers who do not have sufficient land to grow fodder crops. Scenario of fodder availability till 2025 is as below (Table 11).

Table 11. Scenario of Feed and Fodder Availability and Future Requirement (in M T)

Year	Supply (In million tonnes)		Demand (In million tonnes)		Deficit as % of demand (actual demand)	
	Green	Dry	Green	Dry	Green	Dry
1995	379.3	421	947	526	59.95	19.95
2000	384.5	428	988	549	61.10	21.93
2005	389.9	443	1025	569	61.96	22.08
2010	395.2	451	1061	589	62.76	23.46
2015	400.6	466	1097	609	63.50	23.56
2020	405.9	473	1134	630	64.21	24.81
2025	411.3	488	1170	650	64.87	24.92

Source: Draft Report of Working Group on Animal Husbandry and Dairying for Five-Year Plan (2002-2007, Govt. of India, Planning Commission, August-2001).

Pearlmillet is the better crop for fodder scarcity. Rajasthan constitutes about 49% area and 39% of production of pearlmillet in the country, followed by Maharashtra with 17% area and 15% production and Gujarat with 10% area and 14% production. The dual purpose nature of pearl millet offers both food and fodder security in semi arid tropical regions of the country. Four hybrid varieties were released in India (MH 1234, MH 1236, MH 1192, and MSH 155) which would help in providing food and fodder security for people of drought prone areas. Six improved varieties of fodder crops have also been identified (guinea grass, setaria grass, two varieties each of hybrid napier (cross between napier grass and bajra) and cowpea. These varieties will help in increasing fodder production in the country.

In the low rainfall areas 450-750 mm such Bhilwara district, Rajasthan, Central Himalayan Rural Action Group (CHIRAG) introduced community fodder systems. Through the fodder programme CHIRAG has been able to bring back these areas into true common property, the emphasis is to increase access to leaf litter, fodder and fuel wood production through plantation on common and private lands. Fodder access to feed livestock is particularly important, therefore the goal of CHIRAG is not only to increase the quantity of fodder available, but also to increase the number of months during which green fodder is available in the region. To achieve this goal, CHIRAG introduced new variety of fodder grasses that would remain green for longer periods, regenerate faster, *etc*. Plant fodder grasses and shrubs along the contour trenches and on terraces are also practiced, which encourage the growth of rootstock, enabling the soil moisture levels to go up and ensuring the survival of sapling broad-leaf trees. AICRPDA-NICRA has also introduced community fodder banks in various villages of India (Fig. 4) by efficient utilization of common lands and tank beds in the villages

Fig. 4. Community fodder bank, NICRA village, Rajasamand district, Rajasthan

Integrated Farming System (IFS) for sustainable land management

The integrated farming system (IFS) approach introduces a change in the farming techniques for maximum production in the cropping pattern and takes care of optimal utilization of resources. Crops, livestock, birds and trees are the major components of any IFS. No single farm enterprise is likely to be able to sustain the small and marginal farmers without resorting to integrated farming systems for the generation of adequate income and gainful employment year round. Integrated farming system has revolutionized conventional farming of livestock, aquaculture, horticulture, agro-industry and allied activities. A common characteristic of integrated farming systems is that they invariably have a combination of crop and livestock enterprises and in some cases may include combinations of poultry, agro-forestry, horticulture, apiary *etc*. Further, there are synergies and complementarities between different enterprises that form the basis of the concept of IFS (Radhamani *et al*. 2003).

Integration usually occurs when outputs (usually by-products) of one enterprise are used as inputs by another within the context of the farming system. The difference between mixed farming and integrated farming is that enterprises in the integrated farming system are mutually supportive and depend on each other (Csavas 1992). The IFS approach also has the potential to overcome multifarious problems of farmers including resource degradation, declining resource use efficiency, farm productivity and profitability. Traditionally, farmers in rainfed regions practice crop-livestock mixed farming systems, which provide stability during drought years, minimize their risk and help them to cope with weather aberrations. However, these traditional systems are low in productivity and cannot ensure livelihood security now. Hence, it is imperative to improve the existing farming systems to enable adequate employment and income generation, especially for small and marginal farmers who constitute more than 80% of the farming community. Diversification of farming activities improve the utilization of labour, reduce unemployment in areas where there is a surplus of underutilized labour and provide a source of living for those households that operate their farm as a full time occupation (Gopinath *et al.* 2013).

In the mixed rainfed farming systems in India, (agro ecological zone of warm semiarid tropics) one of the solutions suitable for low rainfall (450-750 mm) areas is the *Acacia leucophoea* + *Cenchrus ciliaris* based sylvi-pastoral system, which is an integrated farming system that provides adequate fodder for goats and sheep, along with firewood to meet household requirements. Annual crops like maize and sorghum can be grown between tree rows to maximize the benefits under sylvi-agriculture systems. This practice is suitable for protecting the soil and reducing soil erosion. The *Acacia leucophoea* + *Cenchrus ciliaris* sylvi-pastoral system is most suitable in low rainfall zones with less than 700 mm of rainfall. Small farmers benefit most from the sylvi-pastoral system; and also landless people with livestock may benefit. In the productive farming system model (3 X 3 matrix) land capability, rainfall and soil type, which is based on the research outcomes of AICRPDA network, will be an efficient land management tool for land use planning decisions and implementation (Fig.5).

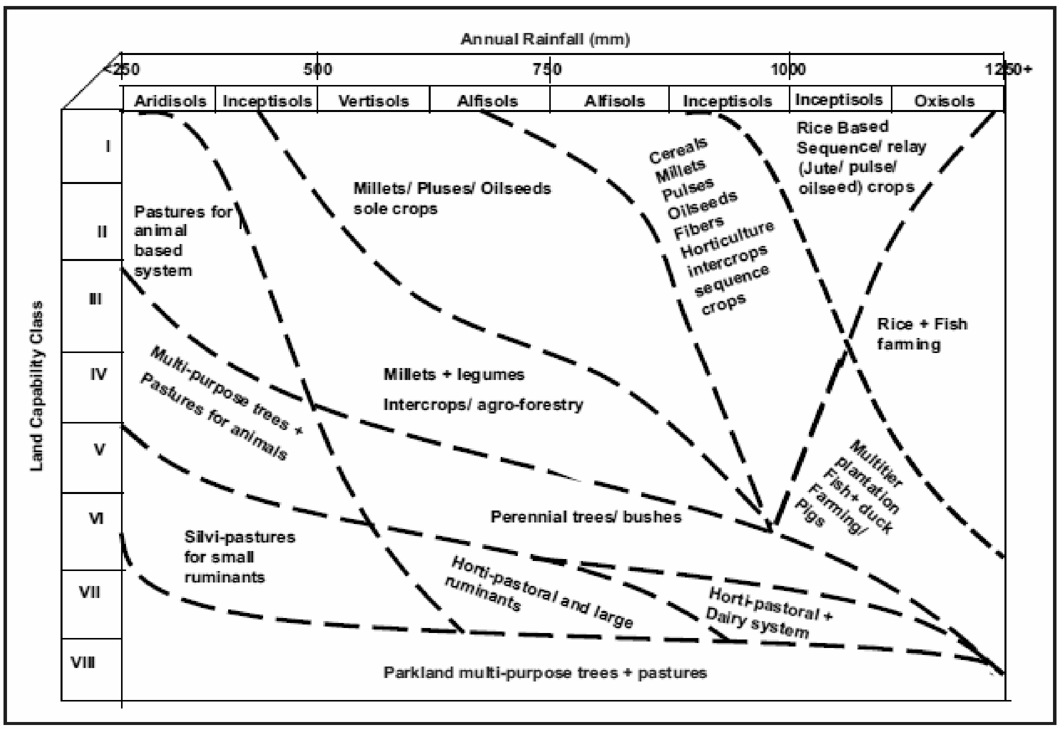

Fig. 5. Productive farming systems matrix in rainfed agriculture (Source: Vittal *et al.* 2003c)

Efficient farm mechanization - key strategy in efficient land use planning implementation

In efficient implementation of agricultural land use planning, farm mechanization (need based) may become important particularly during the situations of weather aberrations like delayed onset of monsoons and early season drought. In the recent past, due to high degree of weather aberrations, the timeliness of agricultural operation such as sowing or intercultural operation exists for a short period of time. If the farmer fails to complete the operation within the ideal time frame, he will have to compromise with the output. This calls for promotion of appropriate farm machinery for performing critical agricultural operations. Although many efforts have gone in this direction in the past, not much dent has been made in improving the timeliness of agricultural operations. Indian agriculture is undergoing a gradual shift from dependence on human power and draft animal power to mechanical power because maintenance of draft animal power and manual labour is becoming increasingly costly coupled with scarce availability of fodder and feed to animal. Hence mechanical power has become more economical and indispensable to meet targets of timeliness and efficient utilization of natural resources and input use. Use of high capacity and energy efficient farm implements are more important in changing climate scenario.

The farm implements availability is essential for completion of sowing operations in narrow sowing window when monsoon gets delayed. Aberrations of monsoon like insufficient and heavy rainfall often warrant resowing of crops, which require adequate draft power in such cases, custom hiring centres are of great help. Timely and precision sowing of *kharif* crops and limited soil moisture availability window is very essential and can be accomplished through need based farm mechanization. For example, by using Anantha ground planter in Anantapur district under delayed onset of monsoon, groundnut was sown in large area in time with precision which resulted in better establishment of crop and higher yield (Venkateswarlu *et al.* 2012).

Agro advisories: Tools in efficient land use implementation

Agro advisories apart from their conventional function of providing knowledge for improved agricultural productivity are expected to fulfil a variety of new functions, such as linking smallholder farmers to high-value and export markets, promoting environmentally sustainable production techniques, and coping with the effects of other health challenges that affect agriculture (Anderson 2008). As part of the All-India Coordinated Research Project on Agrometerology (AICRPAM), CRIDA has developed a model to predict the national food grain production, which is about eight months in advance to the Government of India's estimation using the monthly rainfall received at different meteorological centres. Besides, thematic maps have been prepared and a website called cropweatheroutlook.org has been developed to provide accessibility of agro-advisers and meteorology-links to the farming community.

Through AICRPAM-NICRA, there are plans for piloting the operationalization of the district/block level agromet advisory services during droughts and floods through KVKs/ district line departments. Farmers require information on weather, soil, fertilizer and pesticide that are specific to their plot of land. They need information on the type of seeds, crops available in the market and local market prices. Therefore, the Tata Consultancy Services (TCS) have started a mobile agro advisory system which connects farmers with an ecosystem that empowers them to make sound decisions about agriculture, drive profits and conserve the environment.

AICRPAM assessed the economic impact of Agro Advisory Services (AAS) through a feedback questionnaire filled by two AAS adopting villages and two AAS non-adopting villages. It was concluded from the analysis of feedback that in tobacco crop, 20 % higher net returns were obtained by AAS farmers as compared to non-AAS farmers. In potato, nearly 11 % higher net return was achieved by AAS farmers compared to non-AAS farmers. In the 450-750 mm rainfall regions of Bijapur timely control of pest following agromet advisory increased yield of pomegranate by about 15 % and also helped in improving quality of produce by saving 3 sprays in pomegranate (AICRPAM 2009).

Role of cutting edge research and modern tools in efficient land use planning

The agriculturally low rainfall regions has high potential, if natural resources particularly land, soil and water are scientifically and efficiently managed. Potential of conservation agriculture, precision agriculture and efficient rain water management (with package of harvesting, storing, cost effective lifting and using micro irrigation methods), the crop diversification, agro-ecologic specific real time contingency planning to be perfected in low rainfall regions. The synergy of modern sciences like remote sensing, information and/modern communication technology, and techniques like Geographic Information System, and Global Positioning System with other sciences has to be integral in the on-going and future agricultural research for better land resource management in low rainfall regions. This will also help in better targeting of technologies and also indentifying production and marketing environments.

Efficient land use planning implementation in convergence with national and state government schemes/ programmes

The study, on individual land under MGNREGA (Mahatma Gandhi National Rural Employment Guarantee Act), has pointed to gaps in the planning and the monitoring of assets. The MGNREGA was extended to works on lands of individual beneficiaries like small and marginal farmers. The study found that 85 % of beneficiaries have claimed an improvement in the quality of their land and “a majority of the households noted a 10-15 % increase in income” after creation of assets through MGNREGA. Development of pasture lands apart from meeting the demand of fodder will provide employment opportunities for the rural poor to strengthen their livelihood base and supply fodder for the landless cattle rearers.

Delineation of Soil Conservation Units (SCUs), Soil Quality Units (SQUs) and Land Management Units (LMUs) from the detailed soil survey maps at cadastral level in a microwatershed would help in land resource management information since these units are homogeneous and have a wider application. A resilient, less risk prone farming system based on the land requirements and farmers’ capacities is developed to mitigate the drought and to address the unabated land degradation and imminent climate change. Further, SCUs are basically for soil and water conservation prioritized activities to mitigate drought and could be linked to programmes like MGNREGA in a watershed/ village to create physical assets like farm ponds *etc*. SQUs are to address soil resilience and improve soil organic carbon, problem soils amelioration and wastelands treatment and linked to various schemes and programmes in operational like National Horticultural Mission (NHM), Rashtriya Krishi Vikas Yojana (RKVY), *etc*. SCUs and SQUs are merged in GIS environment to delineate land parcels into homogenous Land Management Units with farm boundaries. LMUs would be operationalized at farm level for taking decisions on arable, non-arable and common lands for cropping, agroforestry, agro horticulture, *etc*., and further, for leaving the most fragile land parcels for ecorestoration. Rainfed land use planning modules should be based on these units for risk minimization, enhanced land productivity and income, finally for drought proofing (Ravindra Chary *et al.* 2005).

Policy interventions

Weather insurance: an adaptation strategy in land use planning implementation

Managing risk is one of the key elements in overcoming the drought effects. Crop insurance appears to have a favourable impact but it entails high cost to the government. A pioneering rain insurance scheme, which was an area approach, for old Mysore and India was proposed to protect farmers against drought. Subsequently in 1970, an individual approach was introduced which was not practicable due to huge financial loss. Again in 1979, an area based approach was formulated and was taken up as pilot scheme in 3 states and extended to 12 states by 1984 which was discontinued, though there was a good financial performance, due to introduction of Comprehensive Crop Insurance Scheme (CCIS) and operated by General Insurance Company with the main objective of providing a measure of financial support to the farmers in the event of crop failure as a result of drought, flood, *etc*., and other two objectives. This scheme is an area approach and linked to institutional credit. Mishra (1999) pointed out that though this scheme encouraged more inputs use by insured farmers and more net returns and more employment, the country could not benefit much out of the scheme with the enhanced production in subsequent years, hence he suggested rainfall insurance scheme on a pilot scale. Kerr *et al*. (1999) made similar proposal. Rao *et al.* (1999) suggested that crop insurance should be a private insurance with full backstopping in many sectors like roads, marketing *etc*., and fine-tuning and upgradation technologies in use on external inputs besides improving the water use efficiency. The National Agricultural Insurance Scheme introduced from *rabi* 1999-2000, has some good features like covering all farmers, crops including annual commercial crops, farmers having option to go in for a high sum insurance equal to 150 percent of average yield of notified area *etc*. However, few recent learning examples from the some states in India where weather insurance scheme was implemented by the corporate sector indicates that the effective implementation and benefits to the real beneficiaries would happen when weather data are site-specific and interpreted scientifically. Scientists should look into almost real-time assessment and communication technologies to facilitate better servicing of the insurance policy by instant estimation of economic damages and scientists should also endeavour to diverse sensors for remote sensing of soil moisture, vegetation cover, interpretation methodologies and real-time communication systems, which could be acceptable to the insurance companies as well as policy holders (Samra 2006). Swaminathan (2007) in the report on 'National Policy for Farmers' submitted to the Government of India, proposed an *Agriculture Risk Fund* to be set up to insulate farmers from risks arising from droughts and other weather aberrations.

Capacity building

Land use planning is being the systematic assessment of land parcels for allocating them to right land uses based on land capability and or land suitability in an area and also being implemented by various stakeholders. Hence, the land use planners and implementers need specific knowledge and expertise in this area. Concerted efforts are needed for sensitizing, skill development and need based capacity building of the stakeholders about the constraints and potentials of particular land and their optimum use for enhancing the productivity and income.

Land Use Planning - The challenges

Land use planning appears to be a rational response to the challenge in low rainfall regions. However, it is clear that attempts to meet the challenge are not keeping pace with the escalating severity of the problems.

- *The very first step in land use planning has to be the explicit recognition of different goals of the various stakeholders, and definition of these goals in practical terms. It has become clear that outsiders cannot necessarily identify other people's priorities nor understand how best to meet them, so there must be direct negotiations between all interested parties to establish common goals, to trade-off between conflicting goals and, ultimately, decide between alternative courses of action.*
- *Empowerment of all groups of stakeholders to assume responsibility for land use and management.*
- *Incentives for land users to take the long view rather than opt for short-term exploitation of resources, and some means of restraining the feckless and greedy.*
- Developed over millennia, the accumulated knowledge and biodiversity invoked needs to be preserved as a sound land use planning agricultural heritage system.
- Sharing the benefits of common natural resource base may prove hard to negotiate. But the economic benefits can be significant if flexible transfers of a land and water are permitted within a well-constructed regulatory framework. These initiatives can only succeed if strong commitment is given to the participation of users in planning and investment decisions and the full and open sharing of economic and environmental information.

Conclusions

A low rainfall region is diverse in biophysical and socioeconomic settings, and this need specific attention for implementation of land use planning with location specific, cost effective and stakeholder friendly strategies. Land use planning is for people and by people, therefore the goal of a new integrated approach to planning the use and management of land resources is to make optimal and informed choices on the future uses of the land. Consultations with stakeholders on the development strategies and anticipated results of modern land use projects are crucial to be agreed by all the parties involved, which can be achieved through interactions and negotiations between planners, stakeholders and decision-makers at national, provincial and local levels. This is possible on the basis of efficient, comprehensive data gathering and processing in an appropriate storage and retrieval system, through a network of nodal institutions. The output of the resulting evaluation of the data will be understandable and user-friendly. The plan will enable all stakeholders to co-decide on the sustainable, equitable and economic use of the land and follow it through to successful implementation.

Way forward

For efficient land use planning, long term planning (over a 50 year horizon) is necessary for sustainable land use in rural areas, backed by 10-year periodic action plans. There should be a focus on efficiency of land use in all perspectives such as energy, water, transportation, waste management and other critical perspectives. Continued integration of various development projects in agriculture, water *etc*. should be carried out in one planning policy with the relevant body to be in charge of planning over a long term horizon. Compatible planning of various utilities and facilities in the villages/districts for increase in crop production and reduction in greenhouse gases should be the focus of any land use plan.

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