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Integrated land use planning for sustainable rainfed agriculture and rural development: A rainfed agro-economic zone approach

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Abstract: Rainfed agriculture in India remains mainstay for livelihood of the majority of small and marginal farmers. The biophysical and socio-economic characteristics largely influence the rainfed agricultural land use. The impending climate change/variability is likely to accentuate the production related problems in rainfed regions. Both rainfed agriculture and rural development are land based activities; hence an integrated land use planning becomes necessary to achieve sustainable rainfed agriculture and rural development. For this purpose, Rainfed Agroeconomic Zones (RAEZs), as an area approach is discussed. Some of the learning experiences and concepts from the national agricultural research system that may be integral for R & D activities in RAEZs are also discussed. A sound Land Use Policy, separately for rainfed regions, at national level is necessary for creation of RAEZs which are contemplated to achieve much desired sustained development and enhance the livelihoods of the farmers.

Key words: *Rainfed Agroeconomic Zone, Land Use Planning, Sustainable Agriculture, Rural Development*

Introduction:

Rainfed agriculture in India accounts for 48 % of the net cultivated area contributing to 40% of national food basket with 85% coarse cereals, 83% pulses, 70% oil seeds and 55% rice. Rained regions are also home to 81 per cent of rural poor and 66% of the livestock. The details of rainfed area, state wise is presented in Table 1. Agricultural land use in rainfed regions, both temporally and spatially is influenced largely by biophysical and socio-economic parameters.

Table.1. State-wise net sown area, net irrigated area, net rainfed area and per cent rainfed area in India

State	Net sown area ('000 ha)	Net irrigated area ('000 ha)	Net rainfed area ('000 ha)	% Rainfed area
Andaman & Nicobar $	9	2	7	78
Andhra Pradesh (undivided)	9991	4214	5777	58
Arunachal Pradesh	212	56	156	74
Assam	2811	197	2614	93
Bihar*	5332	3394	1938	36
Chandigarh*	1	1	0	0
Chhattisgarh	4683	1323	3360	72
Dadra & Nagar Haveli*	20	4	16	80
Daman & Diu#	3	1	2	67
Delhi @	23	22	1	4
Goa	132	29	103	78
Gujarat*	10302	4336	5966	58
Haryana	3550	3069	481	14
Himachal Pradesh*	542	108	434	80
Jammu & Kashmir	735	317	418	57
Jharkhand	1250	102	1148	92
Karnataka	10404	3390	7014	67
Kerala	2079	386	1693	81
Lakshadweep*	3	1	2	67
Madhya Pradesh	14972	6892	8080	54
Manipur*	233	52	181	78
Meghalaya	283	62	221	78
Mizoram	123	10	113	92
Nagaland	361	73	288	80
Orissa	5574	2180	3394	61
Pondicherry	19	16	3	16
Punjab	4158	4073	85	2
Rajasthan	16974	5850	11124	66
Sikkim*	77	14	63	82
Tamil Nadu	4892	2864	2028	41
Tripura*	280	58	222	79
Uttar Pradesh*	16589	13457	3132	19
Uttarakhand	741	338	403	54
West Bengal*	5256	3112	2144	41
All India	**140022**	**63256**	**76766**	**55**

Source: Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India .*The figures are taken from latest Forestry Statistics Publication, Agriculture Census or estimated based on latest available year data received from the States/UTs respectively. ; @ Data refer to 2007-08; # Source is CMIE, 2005-06; $ Source of data is Directorate of Economics and Statistics, A & N Administration and data refer to 2008-09.

Climate change/variability

There is now adequate evidence about the impending climate change and the consequences thereof (IPCC 2007). Though climate change is global in its occurrence and consequences, it is the developing countries like India that face more adverse consequences. The significant aspect of climate change is the increase in the frequency of occurrence of extreme events such as droughts, floods and cyclones adversely impacting climate sensitive sectors such as agriculture (IPCC 2007).

Rainfed regions constitute agricultural lands usually sown with no or little irrigation including groundwater. Need for irrigation becomes less important in rainfed areas receiving high rainfall (regions like Assam, Meghalaya, and Kerala). On the other hand moisture inadequacy is more acutely felt in rainfed regions with low rainfall and high potential evapotranspiration (PET) demand. In view of this rainfed areas may be divided into two classes *viz*., dry rainfed areas and wet rainfed areas based on moisture stress in those regions. The regions where precipitation falls short of PET demand may be termed as moisture stress regions and the counterpart becomes moisture surplus region. Extent of moisture stress may be assessed using moisture index (MI) defined by Thornthwaite and Mather (1955) and simplified by Krishnan (1992) using annual averages. MI = [(P-PET)/PET] 100, where P is average annual precipitation and PET is average annual potential evapotranspiration. MoRD (1994) suggested scientific criteria on the basis of moisture index and level of irrigation for making a district eligible to Drought Prone Area Programme (DPAP) or Desert Development Programme (DDP). Accordingly the regions with the following criteria qualify to be called as dry rainfed areas.

Ecosystem (Moisture Index)	% irrigated area
Arid (< - 66.7)	upto 50%
Semi-arid (-66.6 to -33.3)	upto 40%
Dry sub-humid (-33.2 to 0)	upto 30%

Krishna Kumar (2011) observed rising mean temperatures for India during post 1970 period. The temperature rise affect moisture index at least at macro level though there may be spatial variation at a smaller geographical scale. Raju *et al.* (2013) assessed moisture index based climate at district level using rainfall and PET for period 1971-2005. Climatic shift occurred were compared to the climatic classification given by Krishnan (1988) using climatic data of pre 1970 period. Significant reflections resulting from the study indicated a substantial increase of arid region in Gujarat and a decrease of arid region in the state of Haryana. Other notable observations included the increase in semi arid region in Madhya Pradesh, Tamil Nadu and Uttar Pradesh due to shift of climate from dry sub-humid to semi-arid. Likewise, the moist sub-humid pockets in Chhattisgarh, Orissa, Jharkhand, Madhya Pradesh and Maharashtra states have turned dry sub-humid to a larger extent. The study of Raju *et al.* (2013) indicated climatic shifts in about 27 % of geographical area in India. As per Govt. of India (2012) statistics, net irrigated area (NIA) as per cent of net sown area (NSA) in India increased from 33.58 during 1990-91 to 45.18 during 2009-10. Considering the observed changes in climate and the investments made in expansion of irrigation, the eligibility of districts to DPAP (Drought Prone Area Programme) and DDP (Desert Development Programme) was revisited by Venkateswarlu *et al.* (2014) as per the criteria of MoRD (1994). The number of districts eligible to DDP and DPAP now are 22 and 121 respectively. As per the study, these 143 districts (121+22) may be considered as dry rainfed districts. Three DPAP districts *viz*., Porbander, Amreli and Bhavanagar of Gujarat state are now eligible for DDP due to change of climate from semi-arid to arid. A total of 27 districts are newly found eligible to DPAP. Majority of these districts are form eastern region (Orissa, Chhattisgarh and Jharkhand) due to discernible shift in climate from moist sub-humid to dry sub-humid in this region. A substantial increase in aridity was evident in Gujarat. In many districts of Madhya Pradesh (8), Tamil Nadu (7), and Uttar Pradesh (4), there has been a shift in climate from dry sub humid to semi-arid while a greater extent of climate shift from moist sub-humid /humid to dry sub-humid was observed in Odisha (12), Chhattisgarh (7), Jharkhand (4) and Madhya Pradesh (5) (Fig.1).

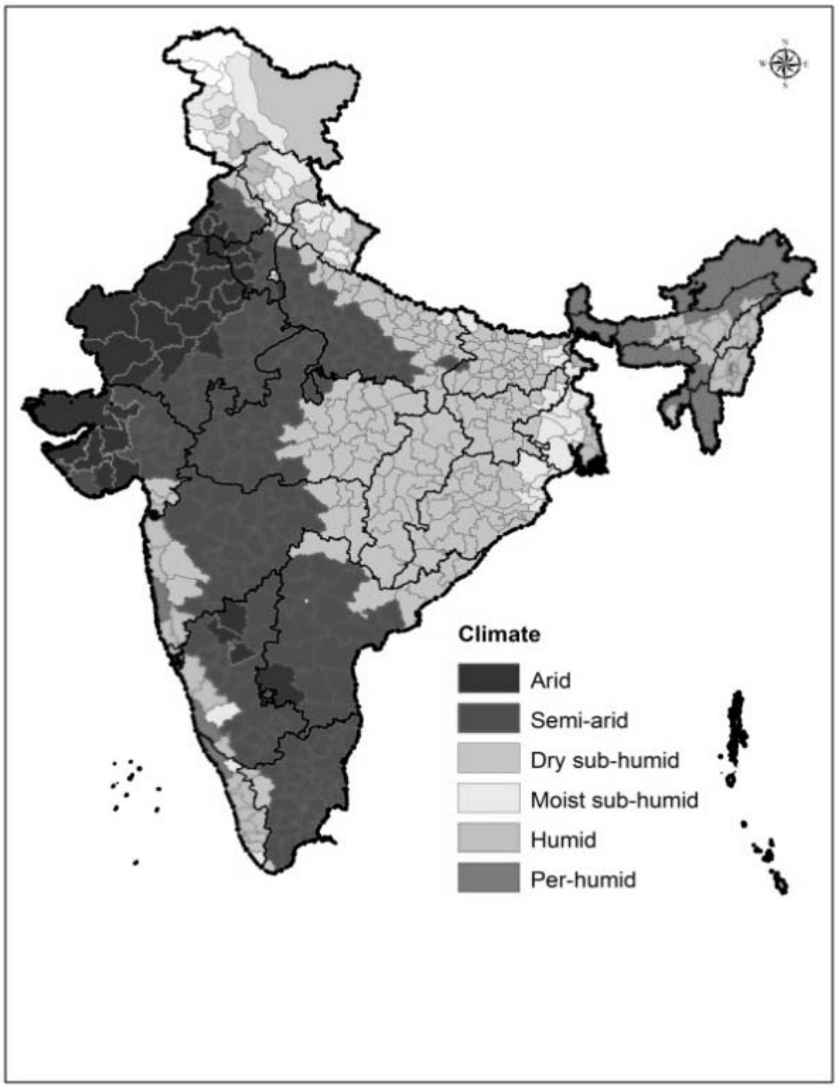


Fig.1. Climatic classification at district level (1971-2005) (Source: Raju *et al.,* 2013)

A micro level study on climate variability and its impact on rainfed agricultural land use in Bhilwara district, Southern agro-climatic zone of Rajasthan indicated that the annual rainfall was decreasing by 46 mm in the last 40 years, reduction in number of rainy days in last 10 years, 21 years found to be arid and 23 years found to be semi-arid in the last 45 years. In the last 15 years, shift in onset of monsoon observed, due to which the sowing window of maize shifted from 7th July to 20th July. This also impacted in high frequency of mid-season and terminal drought influencing change in varieties of *kharif* and *rabi* crops. There was change in cropping pattern for the last 20 years *i.e*. rainfed maize is replaced in the last 5 years by sesame, cluster bean and fodder sorghum. In the last 10 years, area under fodder sorghum/ black gram/ sesame-fallow system has increased and area under maize-wheat has reduced and replaced in some areas with soybean – wheat/ maize-mustard/ taramira system. In *rabi*, area under mustard and taramira increased (Ravindra Chary *et al.* 2008). More than seasonal rainfall, the distribution is more important for rained crops, particularly during *kharif* season; further long dry spells have significant negative impact on fodder and grain production indirectly affecting the livestock production. Due to increased rainfall intensities, land degradation is likely to increase in future. The expansion of rainfed agriculture is more and more regions become arid and semi-arid, increased risk of crop failures and climate-related disasters and decreased yields are the important challenges that the changing climate/variability will lead to. These will result in further deepening of poverty and food insecurity and loss of livelihoods of the rural population in the rainfed regions. Land use practices also change air quality by altering emissions and changing the atmospheric conditions that affect reaction rates, transportation, and deposition.

Land degradation

The degraded lands particularly with water erosion account 73.27 m ha of arable lands (Anonymous 2008). With depleting vegetative cover, the surface erosion problem is likely to accentuate further. This can further diminish soil fertility and will adversely affect native biodiversity, both above ground and below ground. Coupled with this, the demand for higher productivity would require greater nutrient input.

Agricultural drought

Drought, particularly agricultural drought, either in season or within year is recurrent in one or the other part of the country every year, thereby influencing agricultural land use and impacting production/ productivity of rained crops, and livelihoods of farmers in rainfed regions. Crop production in rainfed areas is generally affected by chronic (permanent) drought (south-west monsoon for the *rainy season* region and Northeast monsoon for the *rabi* region with low rainfall), ephemeral drought (occurring in early June, July; mid July-August), terminal drought (September-early October periods during crop growth in Southwest monsoon season), and apparent drought (south-west monsoon with high rainfall) (Fig.2). There is a significant difference between chronic and other drought regions (Ravindra Chary *et al.* 2010).

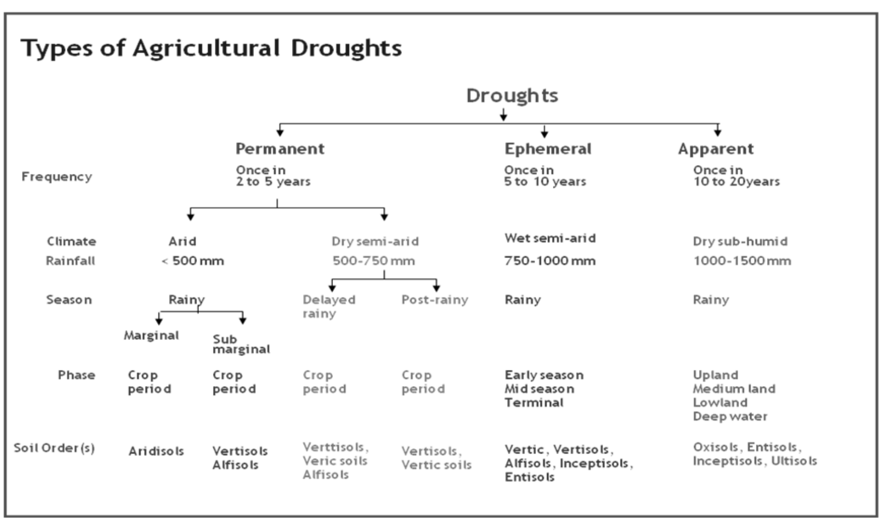


Fig.2. Types of droughts in rainfed regions in India (Vittal et al. 2003)

In view of the vagaries in monsoon rainfall, agricultural drought can be anticipated to occur at any time within the crop growth period of the rainfed crops. In India, the drought regions can be classified into six regions (Fig.3) based on the frequency of drought, climate, rainfall season, soil quality and soil orders (Vittal *et al*. 2003). In rained regions, the soils are generally degraded in quality and marginal in fertility. Alfisols and Vertisols of peninsular India and Aridisols of extremely dry climates are the principal soil orders in dry areas, although Entisols and Inceptisols also occur, especially in toposequences. Vertisols, Alfisols, Entisols and associated soils are the major soil orders extensively under rainfed crops. About 30% of dryland area is covered by Alfisols and associated soils while 35% by Vertisols and associated soils having Vertic properties and 10% by Entisols of the alluvial soil regions. Rainfed farmers practice high diversity in cropping systems with livestock integration which is an inbuilt risk management strategy.

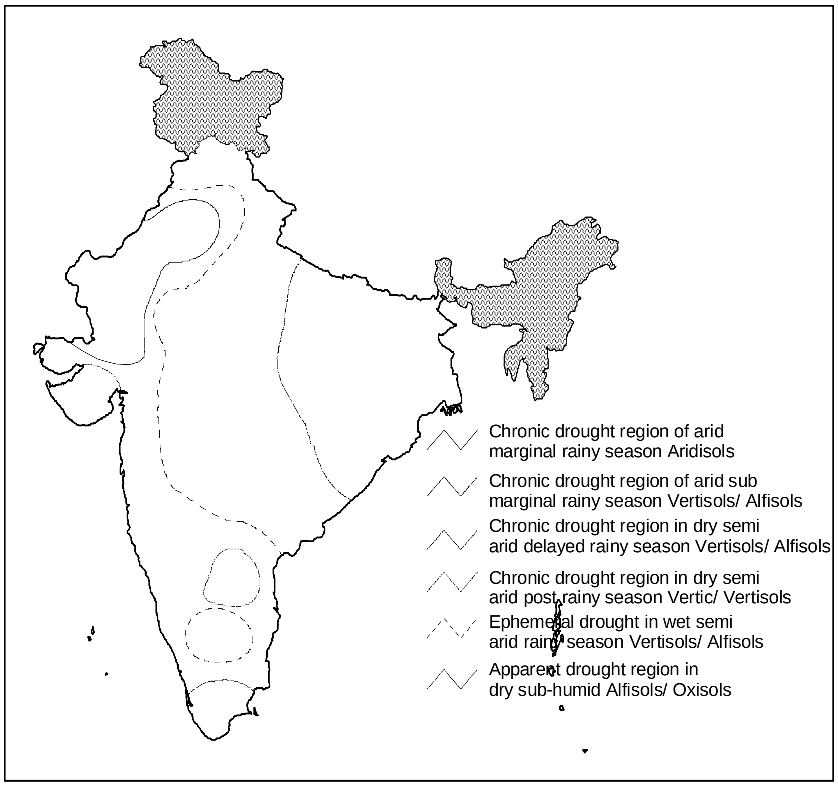


Fig.3. Spatial distribution of agricultural drought regions in India (Source: Vittal *et al.* 2003)

Land use pattern

The district level land use classification (9 fold) statistics from various sources (CRIDA-ICRISAT database compilation, Directorate of Economics and Statistics, Dept. of Agriculture & Cooperation, Govt. of India, respective State governments' publications, CMIE *etc*.) was compiled an the area in each of the 9 land use classes was aggregated for the 143 dry rainfed districts (117 m ha) indicated that the two thirds of the land use is occupied by sown area and forests. Culturable waste is about 8 m ha. The two type fallows together constitute 10 % of the land. It implies that nearly 20 m ha of land is lying idle (fallows + culturable waste) which can be put to economic use (Fig.4).

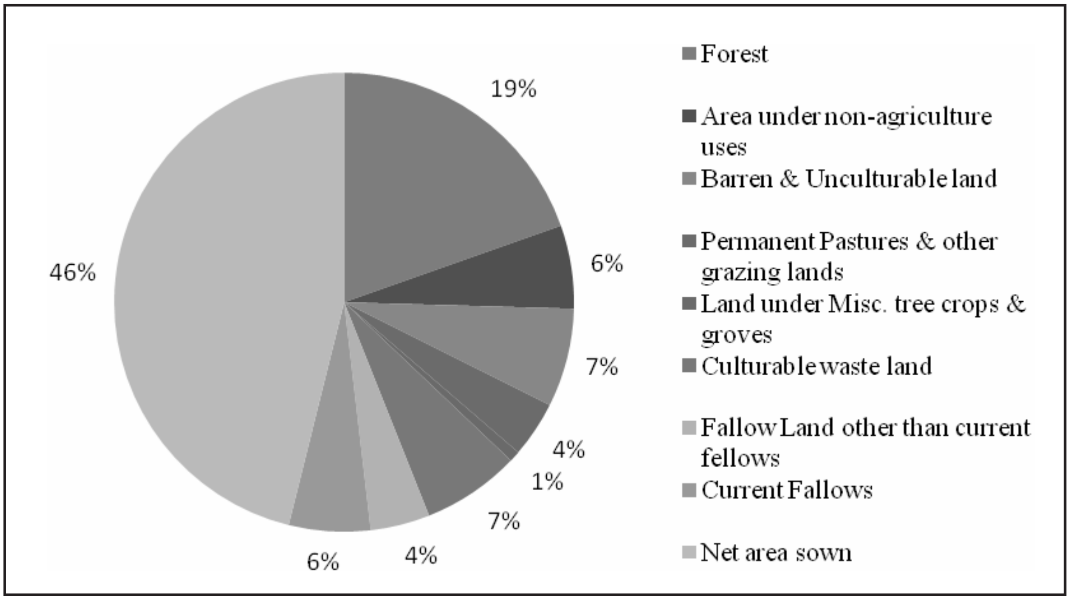


Fig.4. Land use pattern in dry rainfed areas of India

Cropping pattern

The cropping patterns have evolved based on the rainfall, length of the growing season and soil types. However, in recent decade, the land use diversification witnessed due to changed consumer preferences and market demand, farmers are now rapidly shifting to crops and cropping patterns which are more remunerative. For example in Andhra Pradesh, the triggers for recent land use diversification in rainfed areas are: availability of new technologies and high returns (e.g. high yielding maize hybrids, Bt cotton *etc*.), possibility of mechanization and good returns (300% increase in area of bold seeded chickpea on black soils in Prakasham and Kurnool district in one decade), non availability and rising labour costs and assured markets (*e.g.* Subabul and eucalyptus based farm forestry in 1.5 lakh ha. in Guntur, Prakasam, Khammam and Krishna districts in one decade on soils which are good for pulses and oilseeds, government programmes (*e.g.* National Horticulture Mission triggering area under horticulture in several districts due to incentives like subsidy on drip irrigation and planting material *etc*.), processing facilities (*e.g.* soybean area in Adilabad) and unfavourable weather/climate variability (*e.g*. sharp decline in short duration pulse area in Khammam, Krishna and Warangal districts due to rains during harvest).

Yield gaps

The demand for food grains in India is projected to be 308.5 m t by 2030 taking base year as 2004-05 while the supply of food grains is projected as 265 m t based on projected population growth (0.95 per cent per annum), thus leaving a gap of 43.1 m t. Diversification of land use is likely to be more in rainfed areas compared to irrigated and the contribution of rainfed agriculture would remain same at 44% to the total food grains. The yield gap between the research station and on-farm demonstrations and on-farm demonstrations and farmers field are to be bridged at least to bring productivity of rainfed crops to the tune of 1.5 to 2 t/ha in farmers fields which is a challenging task. This can be addressed through land resources management with scientific land use planning.

Socio-economic parameters

The socio-economic parameters indicate an ample scope for investments in rainfed regions for overall development of the people, particularly the livelihoods of the farmers in rainfed regions (Table 2).

Table 2. Relative Characteristics: Rainfed *vis-à-vis* Irrigated regions

Parameter	Rainfed regions	Irrigated regions
Poverty ratio (%)	37	33
Proportion of agricultural labour (%)	30	28
Land productivity (Rs./ha)	5716	8017
Proportion of irrigated area (%)	15	48
Per capita consumption (kg/year) of :		
• Cereals	240	459
• Pulses	20	12
• Total food grains (kg/year)	260	471
Cooperative credit (Rs./ha)	816	1038
Bank Credit (Rs./ha)	1050	1650
Infrastructure development index	0.30	0.40
Social development index	0.43	0.44
Number of predominant crops	>34	1* , 2**

Note: * Rice-Rice in South India-wheat or Cotton-wheat in North India (Source: CRIDA Vision, 2030);
Source: 1. Source of Estimates of 17th to 4th rounds: NSO Report No.407; 2. GoI-NSSO 2006, p. 1.

Operational holdings and size of holdings

Number of small and marginal holdings were found be on increasing trend (from 50 to 118 millions) (Fig. 5). As a result, the average size of holding became 1.15 ha in 2010-11 from 2.28 ha in 1970-71 (Fig.6).

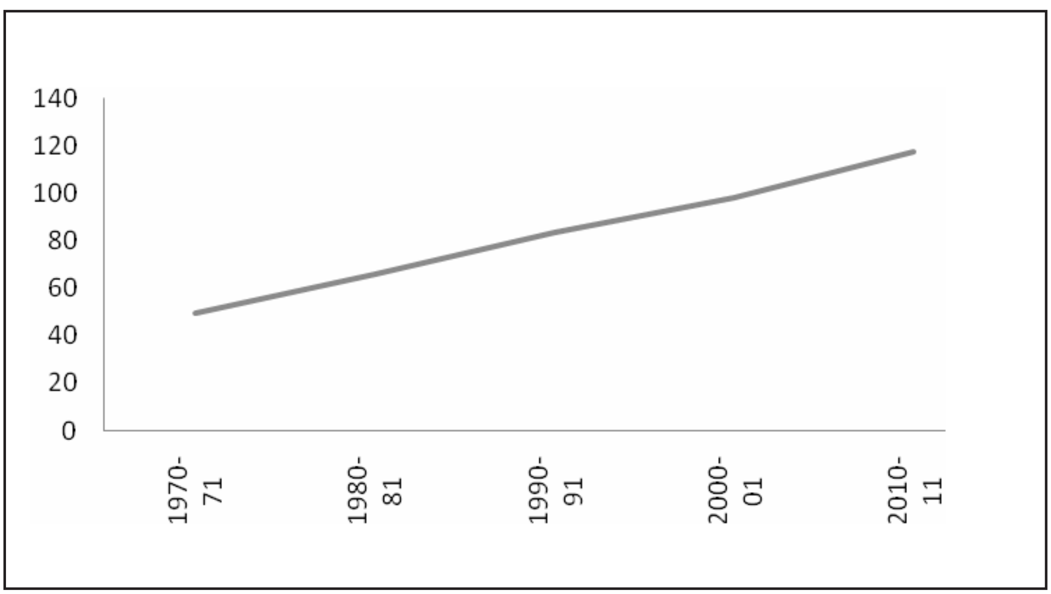


Fig.5. Number of small and marginal holdings (million) in India from 1970-71 to 2010-11 (Source: IASRI, 2014).

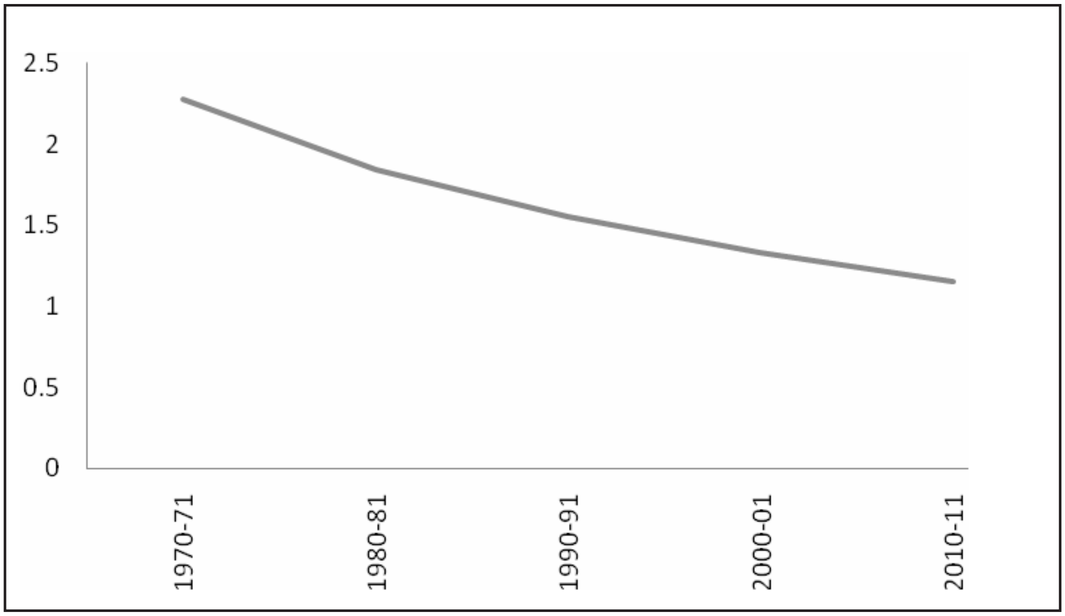


Fig. 6. Average size of holding (ha) in India from 1970-71 to 2010-11
(Source: IASRI, 2014)

Public investments in rainfed regions

There is also an immediate need of additional public investments to conserve natural resources for food security for now and in future as they are our *National Capital*. Post-harvest problems need more attention especially in rainfed areas, which have low management and adoption capacity and inadequate infrastructure. Rainfed areas are mostly monocropped and provide work for four to five months only. The interventions thus need to be designed in such a way that farmers are retained in farming round the year, may be through alternate livelihood options. One of the ways is agroforestry coupled with livestock on watershed mode besides other enterprises which could even be outside agriculture, meeting the local needs (skill enhancement of rural youth in processing and value addition techniques, *etc*.) and provide additional income and livelihood opportunities. In rainfed areas, the suitable interventions (as a basket of options to choose from) need to be propagated and also areas that are suitable for these specific interventions need to be delineated.

Integrated Land Use Planning for Sustainable Rainfed Agriculture and Rural Development

Rainfed agriculture and allied enterprises, rural development activities like watershed management, land conservation/development *etc*. are basically land based activities. Therefore, scientific land use planning at any level forms the basis to achieve sustainable rainfed agriculture and rural development. FAO (1995) defines Sustainable Agriculture and Rural Development (SARD) as a process which meets the criteria of : ensuring the basic nutritional requirements of present and future generations, qualitatively and quantitatively, are met while providing a number of other agricultural products; providing durable employment, sufficient income, and decent living and working conditions for all those engaged in agricultural production; maintaining and, where possible, enhances the productive capacity of the natural resource base as a whole, and the regenerative capacity of renewable resources, without disrupting the functioning of basic ecological cycles and natural balances, destroying the socio-cultural attributes of rural communities, or causing contamination of the environment; and reducing the vulnerability of the agricultural sector to adverse natural and socio-economic factors and other risks, and strengthens self-reliance. The elements and integrated activities for SARD include the policies, instruments, development plans, agrarian reforms, untraditional surveys, food quality and food security, data, monitoring, early warning systems at government level; development of local organization and capacity building for people's participation, training, extension at rural community level; coastal zones, watersheds, river basins, Agro-ecological zones at area level; farming systems, diversification to increase incomes, creation of rural industries, credit and marketing at production unit level and Improving nutrition and food quality, adjusting dietary patterns, product marketing at consumer level.

Land use planning appears to be a rational response to the above challenges. However, it is clear that attempts to meet such challenges 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.
- 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.
- 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.
- Developed over millennia, the accumulated knowledge and biodiversity invoked needs to be preserved as a sound land use planning agricultural heritage system.
- Agrarian structure dominated by small holdings is no handicap for high agriculture production, provided requisite institutional support is available to the small farmers.
- To remain competitive and survive in the current economy, farmers must be insightful, innovative, and ready to make changes. In recent years, conventional wisdom has encouraged diversification with alternative enterprises and increased on-farm processing, packaging, and other means for adding value to raw products before they leave the producer's hands. While this makes good sense, making diversification and value-added strategies work can be challenging (Table. 3).

Table 3. Issues and functions provided by diversification in rainfed regions

Issue	Functions provided by diversification
Productivity and stability	Increased yield, reduce intra seasonal variation and improved stability through diverse components viz. crop, tree, plant and animal
High risk and high cost	Risk and cost minimization through yield and income from annual and perennial mixtures
Unabated land degradation	Minimization of kinds, effect and extent of land degradation by appropriate land care through alternate land use systems
Inadequate employment	Staggered employment round the year
Low profitability	High income generation from various components
Poor energy management	Energy efficient implements and livestock

Participatory Land Use Planning for Management of Agricultural Resources in Rainfed Agroecosystem - Learning experiences

A Mission Mode Project under World Bank sponsored ICAR-National Agriculture Technology Project (NATP) on "Land Use Planning for Management of Agricultural Resources in Rainfed Agroecosystem", was undertaken during 2002-05 by Central Research Institute for Dryland Agriculture (ICAR) as Lead Centre in 16 micro watersheds cross arid, semi-arid and sub-humid agro-ecosubregions with 13 micro-watersheds adopted by 13 network centres of All India Coordinated Research Project for Dryland Agriculture (AICRPDA), 2 regional centres of National Bureau of Soil Survey and Land Use Planning, and one micro-watershed by CRIDA as Lead centre. The project was implemented in a bottom-up and participatory mode. Detailed soil resource characterization in 5258 ha in 16 micro-watersheds lead to delineation of 132 soil-sub groups under five major soil orders (Entisols, Inceptisol, Alfisols, Vertisols and Aridsols). The participatory rural appraisal (PRA) and socio-economic inventory of 1763 households in these micro watersheds indicated 14 biophysical, 9 socio-economic, 9 production, 14 infrastructure and 13 technical constraints for sustaining the land productivity under rainfed situation. The traditional land use across dominant rainfed production systems in relation to soil-site suitability in varying soil types indicated more incorrect agricultural land use practiced by farmers compared to scientific land use (Table 4).

Table 4. Traditional land use in major soils regions in rainfed areas

Major Soils Region	Land Use practiced by farmers	
	Correct # (%)	Incorrect # (%)
Black soils	81(45)	98(55)
Red soils	21(40)	31(60)
Others	20(71)	8(29)
Total	122(47)	137(53)

Source: NATP-MM-LUP- Rainfed Final Report 2006.

The micro-level participatory land use planning process included PRA, farmers' choice and soil-site suitability evaluation for suitability of crops. 932 on-farm demonstrations were conducted in 603 ha at 1294 sites on 132 soil sub-groups on varying topo-sequences in 16 micro-watersheds. This provided much needed land use diversification from the traditional rainfed land utilization. The interventions majority included critical dry land practices, crops and cropping systems. Micro level variations of soils (phases of soil series) and management practices on a topo-sequence are the prime factors influencing land productivity. The simple interventions such as crop/variety on varying soil types revealed yield advantage with increased land productivity within soil types, crops and varieties (Table 5).

Table.5. Performance of improved varieties of rainfed *kharif* crops on various soil types in Doddganganawadi Watershed, Ramanagara district, Karnataka

Soil series	Finger millet					Cowpea		Groundnut	
	MR-1	L-5	GPU-28	HR-911	GPU-26	TVX-944E	KBC-1	TMV-2	JL-24
Channegowdanadoddi (Loamy-skeletal, mixed,isohyperthermic Typic Haplustalfs)	1218	918	1056	700	580	408	481	964	928
Veereegowdanadoddi Sandy,isohyperthermic Typic Ustipsamments)	1187	1021	995	624	570	416	427	918	862
Adishaktihalli (Fine-loamy, mixed, isohyperthermic, Typic Haplustalfs)	1243	949	885	679	686	1193	471	964	958
Doddagangawadi (Fine-loamy, mixed, isohyperthermic, Typic Haplustalfs)	1260	868	845	804	525	473	522	948	786

Source: NATP-MMLUP-Rained Final Report 2006.

Further, in the project, the soybean productivity was assessed in swell-shrink and associated soils with low and improved management practices in four micro-watersheds in Central India, The results indicated a wide spatial variability in soybean productivity influenced by soil-site characteristics and management with higher productivity in *Typic Haplusterts* followed by *Vertic Haplustepts* while it was low with *Typic Ustorthents* under both management levels (Table 6). The study amply indicated a vast scope for bridging the yield gaps in soybean in black soils of Central India with due consideration of land resources and appropriate crop management interventions (Ravindra Chary *et al.* 2008).

Table 6. Soybean productivity influenced by soil types in micro-watersheds in Central India

Soil type	AWC (%)	Soybean yield(kg/ha) LM	IM	Mean
Semiarid (hot moist); Varkhed watershed, Akola district, Maharashtra				
Varkhed -a series: Loamy, mixed, non-calcareous, hyperthermic Typic Ustorthents	9.60	733	813	773
Varkhed-b series: Very fine, semectiic, (calcareous) ,hyperthermic Vertic Haplustepts	10.26	814	1166	990
Varkhed-c series: Very fine, smectitic, calcareous, hyperthermic Typic Haplusterts	13.47	927	1357	1142
Semiarid (hot moist) Jaitpura watershed, Indore district, Madhya Pradesh				
Jaitpura-a series : Loamy-skeletal, mixed, non calcareous hyperthermic Lithic Ustorthents	14.55	614	1158	884
Jaitpura-b:Fine ,mixed ,calcareous, hyperthermic Vertic Haplustepts	7.29	866	1103	985
Jaitpura-c series: Very fine, smectitic, calcareous, hyperthermic Typic Haplusterts	7.08	918	1254	1086
Semiarid (hot moist): Panubali watershed, Nagpur district, Maharashtra				
Panubali-a series: Fine-loamy, mixed, hyperthermic Typic Haplustepts	7.24	530	550	515
Panubali-b series: Fine, smectitic ,hyperthermic (calcareous),Vertic Haplustepts	19.63	856	926	891
Panubali-c series: Fine, smectic,hyperthermic (calcareous) Typic Haplusterts	18.49	995	1060	1027
Sub humid (hot moist), Khuj watershed, Rewa district, Madhya Pradesh				
Khuji-a series: Fine loamy, mixed, hyperthermic Typic Haplustepts	7.33	663	745	704
Khuj-b:fine loamy, mixed, hyperthermic Vertic Haplustepts	12.59	908	1606	1256
Khuj-c: Fine, smectitic, hyperthermic Typic Haplusterts	10.87	1119	1967	1543
Mean		**829**	**1142**	**983**

Further, the results obtained in various micro watersheds revealed promising interventions/ practices such as cotton groundnut (1:1) groundnut (GG-20)+black gram (T-9) and cotton (H8)+sesame intercropping system in deep swell-shrink black soils (*Typic Haplusterts*) in Vagudad watershed, Gujarat; newly introduced *Macuna utilis* a medicinal crop during drought in deep red soils (*Rhodic Paleustalfs*) in Amanishivapurkere watershed, Karnataka; pearl millet (GHB-235) + green gram (GM-4) (3:1) inter cropping in medium deep sandy loam soils (*Typic Inceptisols*), in >100 cm deep black soils, chickpea cv. A and groundnut + castor (7:1) intercropping, in <50 cm deep soil, coriander (improved variety – DWD-3), chickpea cv. A-1 in Gadehotur watershed, Andhra Pradesh; coriander + chickpea + senna relay intercropping as contingency crop planning to cotton crop in medium deep swell-shrink black soils (*Typic Haplusterts*) in Chidambarapuram watershed, Tamil Nadu; soybean pigeonpea as sole and as intercrop in deep swell-shrink black soils (*Typic Haplusterts*) at Khuj watershed, Madhya Pradesh; *desi* cotton in medium deep black soils (*Typic Ustochrepts*), sesame cv. AKT-64 (28 q/ha), castor dwarf variety(AKKC-1), cucurbits cv. Ankur Himangi and Matki (local pulse) in deep black soils

(*Vertic Inceptisols*) in Varkhed watershed, Maharashtra; sorghum cv. CSH-9, BJH-117, soybean (JS-335) in deep black soils (*Vertic Ustochrepts*) and introduction of LRK-516 cotton in shallow-skeletal black soils (*Lithic Ustorthents*) and NHH-44 in calcareous medium deep black soils (*Typic Inceptisols*) in Panubali watershed, Maharashtra; introduction of safflower with compartmental bunding, pigeon pea cv. ICPL-87 in intercropping of sunflower + pigeon pea (2:1) in deep swell-shrink black soils (*Typic Haplusterts*) in Sarole watershed, Maharashtra; and diversification to maize, sorghum and pigeonpea based intercropping system in Entisols (shallow sandy clay loams) with 1 to 3 % slope under well drained uplands and medium lands and crop substitution with chickpea in place of wheat in *Udic Eutrudepts* at Ballipur watershed, Uttar Pradesh. All these interventions amply demonstrated increased land productivity by 30 to 50 per cent and in few cases more than double, with scientific land use planning in rained regions (NATP-MMLUP - Final Report 2006).

With the outcomes and experiences from NATP-MM-LUP Project, Ravindra Chary *et al*. (2005) developed a conceptual approach for delineation of Soil Conservation Units (SCUs), Soil Quality Units (SQUs) and Land Management Units (LMUs) from the soil resource information at cadastral level in a micro watershed as these would likely to help in land resource management since these units are homogeneous in a theme and have a wider application. A resilient, less risk prone farming system based on the land requirements and farmers' capacities could be developed to mitigate both *in-season* and impending drought, to address the unabated land degradation and imminent climate change. The SCUs form the basis as to prioritize and implement suitable interventions and programmes/schemes related to soil and water conservation and has a wider scope to converge with programmes like National Rural Employment Guarantee Scheme (NREGS), other various land management/ conservations/development programmes in a watershed mode by Ministry of Rural Development either at Central or at State level. The 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 Rashtriya Krishi Vikas Yojana (RKVY), National Horticultural Mission (NHM), *Boochetana* (Karnataka), Network planning (NABARD) etc. Further, SCUs and SQUs are merged in GIS environment to delineate land parcels in to homogenous Land Management Units with farm boundaries. LMUs would be operationalized ultimately at farm level for taking land resource management decisions on arable, non-arable and common lands for crop intensification/diversification, alternate land use systems like agro-forestry, agro-horticulture, eco-restoration *etc*. Cadastral level Rainfed land use planning modules should be based on these units for risk minimization, enhanced land/water productivity, income drought proofing, land resource conservation, finally for enhancing livelihoods of the rained farmers. An example of delineation of these units for the Kaulagi watershed, Bijapur district, Karnataka is shown in Fig. 7, 8, 9 and 10.

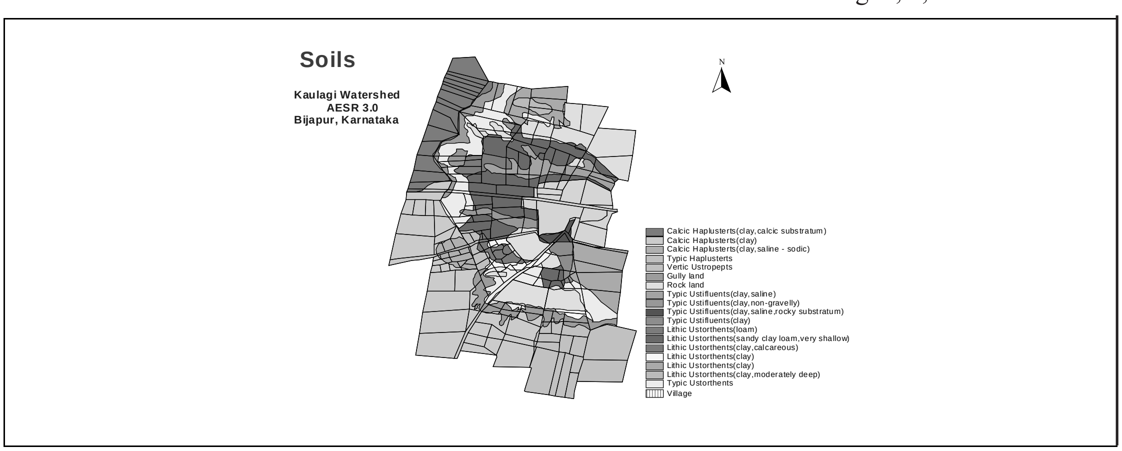
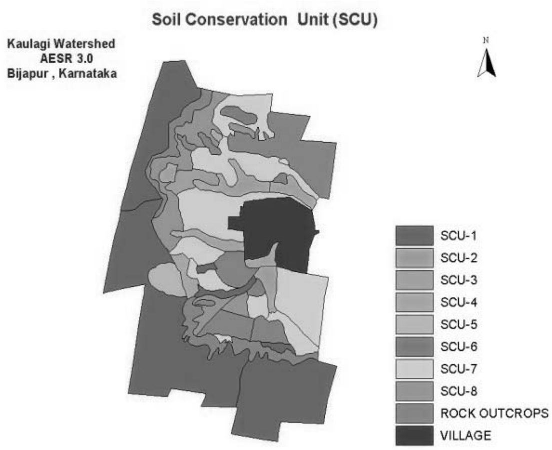
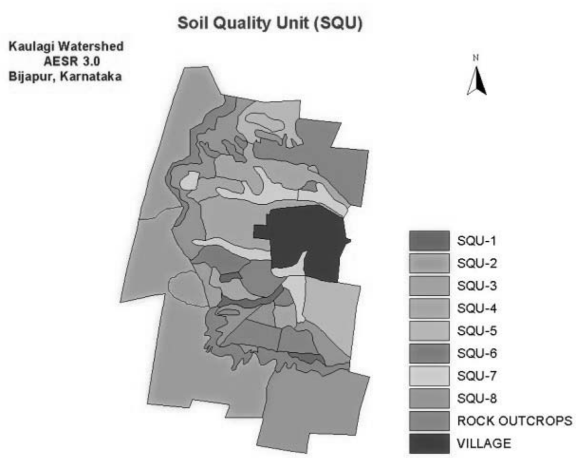


Fig. 7. Soil resource map - Kaulagi watershed, Bijapur district, Karnataka



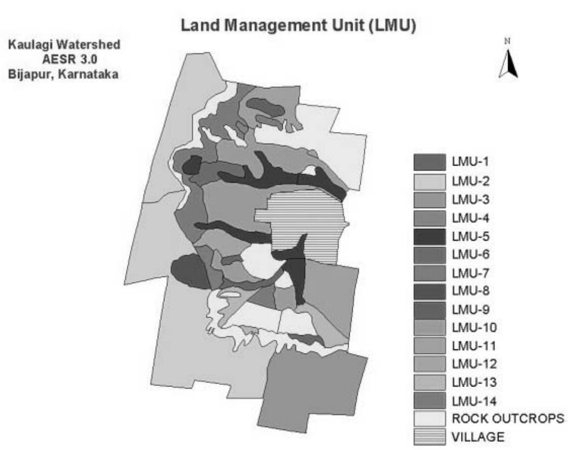
SCU	Details	Area (%)
2	Deep + low erosion	50.23
3	Shallow + very low erosion	7.68
4	Shallow + moderate erosion	1.61
5	Deep + moderate erosion	1.17
6	Deep + high and very high erosion	1.99
7	Very shallow + low erosion	0.83
8	Very shallow + moderate erosion/ Very shallow + high and very high erosion	36.49

Fig. 8. Soil Conservation Units (SCUs) in the Kaulagi watershed, Bijapur district, Karnataka



SQU	Details	Area (%)
1	Non gravel + neutral (pH) + low (OC) + normal (EC) + calcareous ($CaCO_3$)	1.67
2	Non gravel + neutral (pH) + low (OC)+ high (EC) + calcareous	36.76
3	Non gravel + alkaline (pH) + low (OC)+ normal (Eke) +calcareous	1.17
4	Gravel + alkaline (pH) + high (OC) + normal (EC) + calcareous	15.71
5	Gravel + alkaline (pH) + medium (OC)+ normal (EC) + calcareous	10.07
6	Gravel + alkaline (pH) + low (OC) + normal (EC) + calcareous	2.12
7	Gravel + alkaline (pH) + low (OC) + critical (EC)+ calcareous	7.51
8	Extremely gravel + alkaline (pH) + low (OC) + normal (EC) + calcareous (CaCO3)	25.00

Fig. 9. Soil Quality Units (SQUs) in the Kaulagi watershed, Bijapur district, Karnataka



LMU	SCU	SQU
LMU-1	SCU - 1	SQU - 1
LMU – 2	SCU - 1	SQU - 2
LMU – 3	SCU - 1	SQU - 8
LMU – 4	SCU - 2	SQU - 6
LMU – 5	SCU -2	SQU - 7
LMU – 6	SCU - 3	SQU - 4
LMU – 7	SCU - 4	SQU – 3
LMU – 8	SCU - 5	SQU – 2
LMU – 9	SCU - 6	SQU -5
LMU – 10	SCU - 7	SQU – 4
LMU – 11	SCU - 7	SQU – 5
LMU -12	SCU - 7	SQU – 6
LMU – 13	SCU - 7	SQU – 8
LMU -14	SCU - 8	SQU – 8

Fig. 10. Land management units in Kaulagi watershed, Bijapur district

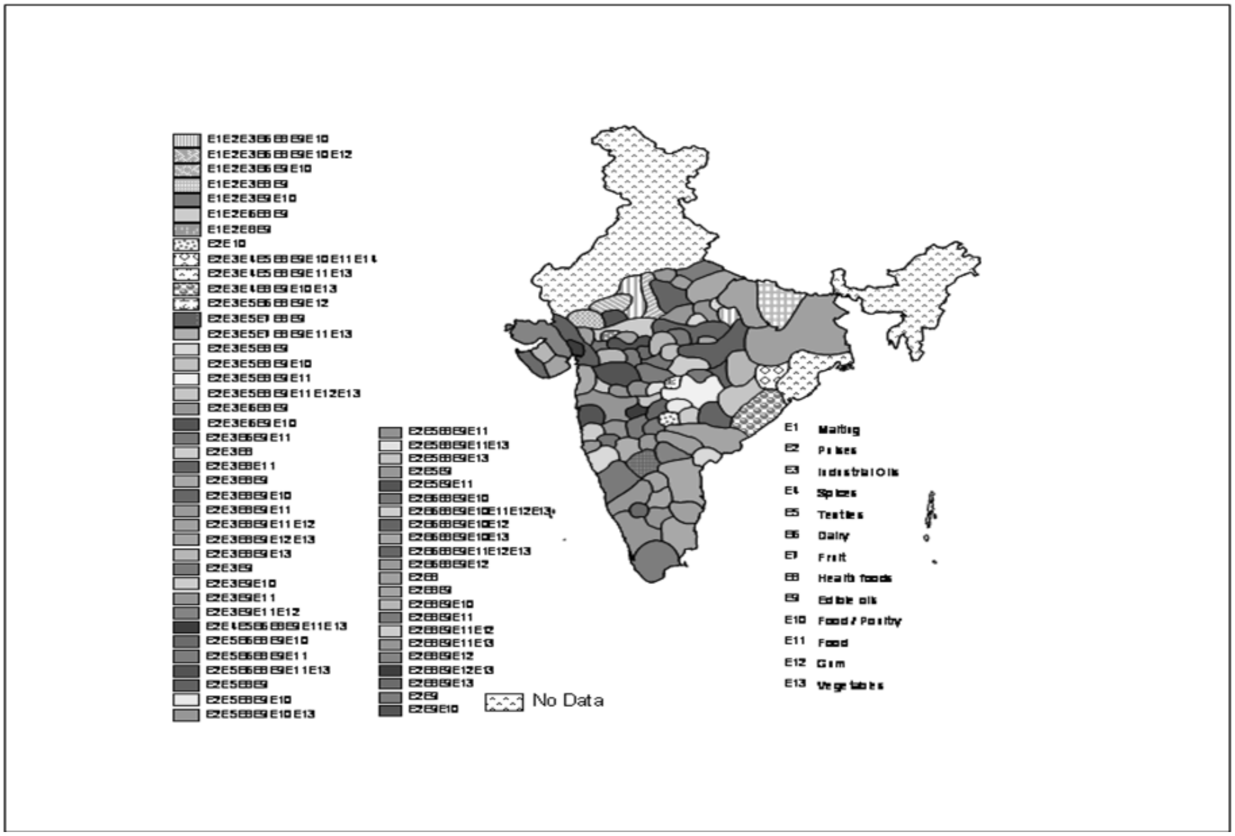


Fig. 11. Land management units (LMUs) in the Kaulagi watershed, Bijapur district, Karnataka
(Source: Background Information, V QRT -2000-01 to 2004-05-CRIDA-AICRPDA)

Agro-entrepreneurship with potential crop diversification in rainfed areas

The recommendations emanated from the various intercropping and sequential cropping studies from different AICRPDA network centres, efficient cropping systems (intercropping and double cropping) were identified. These systems were recommended to similar liars agro-ecoregions. Based on the existing dominant cropping systems and potential cropping systems in these agro-ecoregions and their commercial produce, an agro-entrepuner ship with Potential Crop Diversification in Rainfed Areas map (Fig.11) was generated in GIS environment (Background Information, V QRT -2000-01 to 2004-05-CRIDA-AICRPDA). Agricultural produce, by and large, is sold in the markets without any post-harvest value addition. While the cost of inputs is steadily increasing and that of outputs is either stagnant or redoing, farmers are ending up in loss. Therefore, post-harvest value addition needs an impetus for inducing economic sustainability into farming as an enterprise. Farmers can benefit from better income and more employment opportunities at the village level. Besides, the past decade has shown that dryland horticulture can be a profitable option and has high potential for integrating crop and animal components. This area needs further attention and impetus in the years to come.

Rainfed Agro-economic Zones (RAEZs) - The approach

The existing domain/area specific land based approaches to address rainfed agriculture and rural development like watershed development programmes *etc*. are either sectoral in approach or lack sound scientific basis for land use. Further, the earlier developmental and relief measures focused through Drought Prone Area Program (DPAP) and Desert Development Program (DDP) in drought prone areas, which are primarily located in core rainfed agriculture regions, by the central and state governments could address only some of the drought impacting issues. Besides these, several other approaches were also adopted for delineation of rainfed areas for research and development. The Planning Commission identified 15 agro-climatic regions (ACRs) on geographical basis for development purpose and these ACRs cut across the states. ICAR, in 1979, under National Agricultural Research Project (NARP), delineated country into 127 agro-climatic zones (ACZs) based on soils, climate, topography, crops, vegetation *etc*. However, each ACZ covers 2-4 districts and spread over an area of 40 to 50 thousand sq.km. NBSSLUP delineated country in to 20 agro ecological regions (AERs) and 60 agro-ecologicalsubregions based on bioclimate (rainfall, temperature, vegetation and PET), length of growing period and soilscape (Sehgal *et al.* 1992), Further, Velayutham *et.* al. (1999) have suggested agro-ecological subregions with details of the agro-ecological settings and the land use potentials and constraints of each sub-region, can help to develop alternate land use plan scenarios *etc.* for planning and development. Under National Agriculture Technology Project (NATP) the concept of production system was introduced by ICAR (NATP 2004) for research and extension purpose. In this approach, the rainfed agro-ecosystem was subdivided into 5 homogeneous production systems, *viz*. Rainfed Rice based Production System, Nutritious Cereals (coarse cereals) based Production System, Oilseeds based Production System, Pulses based Production System and Cotton based Production System. Presently, the focused issues in rainfed areas are resource conservation and management, increased productivity and profitability, making rainfed agriculture a viable profession and improving the livelihoods of the farmers/people in rainfed areas. Further, the major issues/ programmes for SARD related to Integrated Land Use Planning are climate variability/change, land degradation, agriculture policy review, planning and integrated programming in the light of the multifunctional aspect of agriculture, particularly with regard to food security and sustainable farm production and farming systems through diversification of farm and non-farm employment and infrastructure development, land resource planning information and education for agriculture , land conservation and rehabilitation, water for sustainable agriculture and sustainable rural development, diversification for income and employment generation, reducing the vulnerability of rural communities to risks and uncertainties. Enabling rural communities for better resilience, traditionally, developmental programmes were imposed in a top - down approach. This approach has been attempted at state, district and village level and data requirements would vary from broad physical resources at state level to more detailed agro-ecological, social and economic resources at micro level.

In light of the rainfed agriculture scenario, SARD issues, land use planning issues discussed earlier, to achieve twin goals of sustainable rained agriculture and rural development , it calls for an entirely a new target domain approach. This could be by delineating core '**Rainfed Agro-Economic Zones'** in a district or part of a region in a state (Ravindra Chary *et.al.* 2008). The important criteria for delineation of these RAEZs could be a predominantly rainfed region with predominant rainfed production system (having 80 % net rainfed area), source and percentage net irrigated area (< 25 % net irrigated area by all sources) and with probability of recurrence of any type of drought *i.e*. permanent, ephemeral and apparent drought. Here, the rainfed farmers' livelihoods improvement and sustaining the land resources would be focal, wherein all the interventions related to land resource management, soil and water conservation, rainwater management (*in situ* and *ex situ*), management of rainfed crops for higher land and water productivity, real-time contingency and compensatory crop planning, farm mechanization for precision and timely agricultural operations will be implemented specific to land resources, marketing opportunities both on-farm (at farm gate) and off-farm, warehouses and cold storage facilities, post harvest value addition with value chain facilities for higher profitability leading to enhanced livelihoods. Instead of individual and piecemeal interventions the entire rainfed production system will be targeted to develop as a Rainfed Agro-Economic Zone (RAEZs) which would act as hubs of rainfed agriculture development. Tools like crop or weather insurance, where the insurance product may have an inbuilt condition that a given product is applicable only if a particular crop or commodity is grown in RAEZs where in the government can subsidize part of the premium for farmers who adopt rational water use. New opportunities are also arising in the area of Clean Development Mechanism (CDM) and carbon credits, which can be implemented in RAEZs where farmers can be compensated for adopting soil, water and energy conservation practices and carbon emission reduction practices, which also contribute to drought amelioration and sustainable productivity on a long term basis, but relatively lower returns on short term. For example, Malwa Plateau zone in Madhya Pradesh could be a RAEZ for soybean based rained production system, Anantapur district in Andhra Pradesh could be a RAEZ for groundnut based production system and so on. Further, these RAEZs could simultaneously address non-arable lands and common lands for suitable and multiple land uses for ecosystem services and other rural development activities. RAEZs akin to Agri-export zones have greater scope in hill and tribal districts of the country with focus on organic farming zones, for example Kandhmal district in Odisha, a truly organic and agri-export zone for rainfed turmeric well supported by KASAM (a farmers' association) and local government.

A Framework of Rainfed Land Use Plan for Participatory Self-Sustaining Viable Bio-diverse Mixed Farming System with activities, relevant partners, strategies and outcomes at different scales was suggested (Ravindra Chary *et al.* 2004) (Fig.12) which may be integral to RAEZ concept for participatory and use planning at cadastral level.

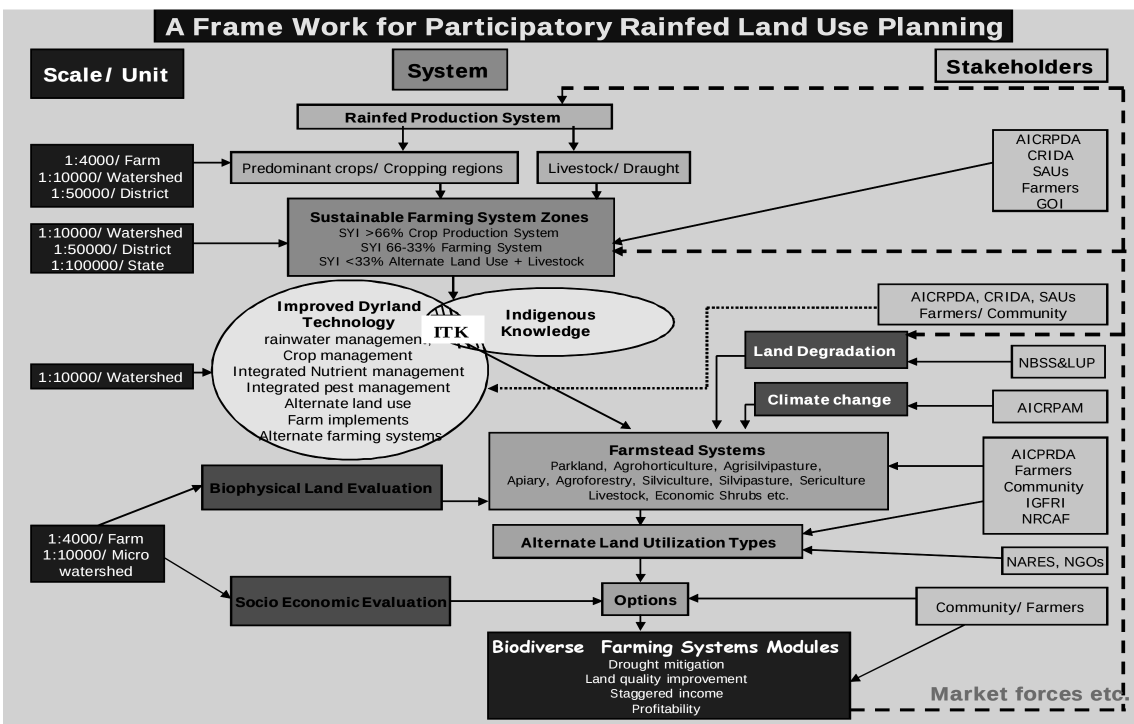


Fig.12. A Framework Particpatory Rained Land Use Planning

AICRPDA- All India Coordinated Research Project for Dryland Agriculture; AICRPAM: All India Coordinated Research Project on Agro-Meteorology; CRIDA-Central Research Institute for Dryland Agriculture; SAU-State Agricultural University; NBSS&LUP- National Bureau of Soil Survey &Land Use Planning; IGFRI-Indian Grasslands and Fodder Research Institute;NRCAF-National Research Centre for Agroforestry; NARES: National Agriculture Research and Extension System (ICAR, SAUs, Private corporate research); NGOs-Nongovernmental Organizations

Conclusion

Rainfed areas are likely to contribute to nation's food basket, support rural livelihoods and a majority of livestock in India. The biophysical characteristics, particularly climate variability and land degradation, and socio-economic parameters, particularly adaptive capacity of the resource poor farmers, continue to influence and impact the agricultural land use, thereby production, productivity and profitability. Though, many rural development programmes are land based either directly or indirectly linked to rainfed agriculture, the approach has so far been sectoral and piecemeal. Integrated land use planning is a buzzword for achieving the different goals of the various stakeholders or a single criterion has sustained the land productivities, incomes, ecosystem and finally the livelihoods reasons being highly complex situations of risk, diverse socio-economic settings and subsistence agriculture. However, to achieve the twin goals of sustainable rainfed agriculture and rural development, integrated lands use planning with sound scientific principles is necessary. For this purpose, a new area/target domain approach *i.e. Rainfed Agro-economic zone"* is proposed which may address arable, non-arable and common lands with convergence of knowledge, programmes/ schemes of state and central governments, and activities by relevant stakeholders. While RAEZ is likely to address all the agriculture and related rural development activities in a target domain with judicious of natural, capital and human resources, it is suggested to look into some of the learning experiences, approaches and concepts while operationalizing the RAEZs. A sound Land Use Policy, separately for *rainfed regions*, at national level, equipped with adequate legislative/judicial powers combined with strong political will, shall promote creation of RAEZs. These RAEZs are contemplated to achieve much desired sustained development and enhance the livelihoods of the farmers in drought prone area and further, pave the way towards achieving "Second Green Revolution" from rainfed areas.

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