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Guidelines on Drought Coping Plans for Rainfed Production Systems

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Abstract

With inadequate water resources for irrigation, India remains at least 50% under rainfed agriculture. In future the rainfed areas are required to meet raising demand of food, pulses, oilseeds, vegetables, fruits, etc. on sustained basis. But the production remains a gamble due to uncertainties in rainfall. Any extended period of water stress especially injurious to plants is termed as drought. Even though the droughts are inevitable and unavoidable, but are manageable. Over decades, several technologies to mitigate drought affects at farm level are evolved. This improved crop husbandry insulates against stress. Drought planning is a dynamic process. Herein, the planning for managing drought based on intensity in a season (severe, moderate, mild and low) based on actual evapotranspiration to potential evapotranspiration in chronic, ephemeral (early, mid and late seasons) and apparent drought situations were described with paths during a season. Drought amelioration techniques by selecting productive farming systems and drought proofing methods based on land capability and rainfall (upto 1500 mm) were included. Information was also given on contingency plans, nutrient management, soil water conservation measures including water harvesting based on land capability, rainfall and soil orders. A collective land use system with perennials, annuals, herbaceous plants, livestock in spatial arrangements or in rotation or both with ecological and economical interactions in an Agroforestry model creates situation where a farmer can manage their own natural resources in a sustainable productive way making them less dependent on external inputs by following the described paths. These micro level farming systems are practicable only in rainfed lands due to resilience in adoption of diversification from crop through tree to animal.

This summary is the culmination of experiences, from both on-farm and research stations, of about 130 scientists in a multi-disciplinary team working in the All India Coordinated Research Project for Dryland Agriculture, started in 1970 with 23 centres spread from arid through semi-arid to sub-humid climatic zones, comprising rainfed rice, oilseeds, pulses, cotton and coarse cereals based production systems.

Cover page : Greening the grey areas

Designed by : I Ram Mohan and KVGK Murthy

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1. Rainfed Agriculture Scenario

In the absence of adequacy of water resources for irrigation, rainfed farming is practiced in nearly two third of the arable land (96 mha) in India. The gross cropped area of the country is 182 mha. Out of an estimated 142 mha net cultivated area, about 67% is rainfed. In this, 76 mha is under irrigation. The National Commission on Agriculture in 1976 predicted that even when the full irrigation potential is tapped by 2013 AD, over 50% of the arable land would continue to remain rainfed in the foreseeable future. So far much of the agricultural growth achieved in past decades occurred in irrigated areas. The potential for additional production gains in these areas may lessen with time from inherent problems. It is in the rainfed belt where cultivation of coarse cereals (91%), pulses (91%), oilseeds (80%) and cotton (65%) predominates. About 44% of the total production is contributed by rainfed region. Rainfed agriculture supports 40% of country's population. The rainfed areas are increasingly being warranted to help meet the raising demand for food, pulses, oilseeds, feed, fuel, fruits, vegetables etc. Thus, the country's economy depends on a sustained increase in the productivity from drylands. Rainfed regions in India encompass a wide range of soil and rainfall conditions.

1.1 Soil

Soils of these regions belong to alluvium (Entisols and Inceptisols), red soils (Alfisols, Oxisols and Ultisols), black soils (Vertic Inceptisols and Vertisols), submontane soils (Entisols, Inceptisols and Mollisols), and sierozemic soils (Aridisols). Among these, red (132 mha) and black (72 mha) soils are largest in extent in the country. Red soils exhibit large variation in pore size distribution, and consequently in water retention, transmission and release characteristics. Black soils possess high water retentivity and unsaturated hydraulic conductivity, which make them suitable for rainfed crops in both the seasons; however, soils with high clay remain prone to oxygen stress because of poor internal drainability through micro-pores in *kharif.* Thus, there exists a wide range of water retentivity, its conductivity and availability to the growing plants. The length of water availability or growing period and growth depends on soil related constraints inherently.

1.2 Climate

It is estimated that the total precipitation in the country is 400 mha-m (million-hectare meters) annually. Of this, around 150 mha-m enters the soil, about 180 mha-m constitutes the runoff, and about 70 mha-m is lost through evaporation. India has, by now, been able to utilize less than 20 mha-m of the 180 mha-m of runoff for all major and minor irrigation projects, thus leaving about 160 mha-m of precipitation that flows freely through rivers into the sea. Rainfall varies with a large variation in its temporal and spatial distribution. The rainfed area in the country can broadly be classified into three climatic regions – arid, semi-arid, and sub-humid. Among many factors contributing to sub-optimal and unsustainable yield levels, availability of excessive water in spells during *kharif* (rainy) season, and water stress of varying degree and duration during *rabi* (post rainy) season figure prominently. The crop yields, thus, largely or entirely depends on the growing season rainfall plus water stored in the soil profile. Due to this rainfed regions are characterized by relatively low and unstable crop yields. Risk is high because rain is undependable in both timing and amount making the region prone to periodic short to long-term droughts.

Dryland crop production is a function of both spatial and temporal availability of soil moisture within the field during the crop growth period. The uncertain drought is a major contributing factor to low productivity, which is estimated at 0.2, 0.6 and 1.0 t/ha against a potential of 1.0, 1.9 and 3.0 t/ha under arid, semi-arid and sub-humid regions, respectively. Drought recurrence is a location specific interaction between soil capacity to retain moisture and precipitation in a region. Agriculture in rainfed areas, thus, continues to be a gamble because farmers in rainfed region face many uncertainties. Rainfall and rainfed crop based production systems of the country are shown in Fig.1.

2. Indigenous Risk Management

The impacts of drought on society and the environment often linger for years after the drought has passed. Older farmers are more likely than younger farmers to say drought as a harsh and long period. More of the younger farmers tend to feel drought as shorter and less severe and expect to see more of milder droughts. Farmers in rainfed agricultural areas have developed their own strategies for reducing their exposure to crop production risk, and for coping with losses when they occur. Traditional risk management strategies have proven effective in managing drought risk, and have enabled rainfed agricultural societies to survive their risky environments for many millennia. Cultural Practices play an important risk-reducing role; they include planting different crops with relatively low covariate yield (either in an mixed/intercrop or on separate fields); diversifying spatially by operating multiple plots with different environmental characteristics; and staggering

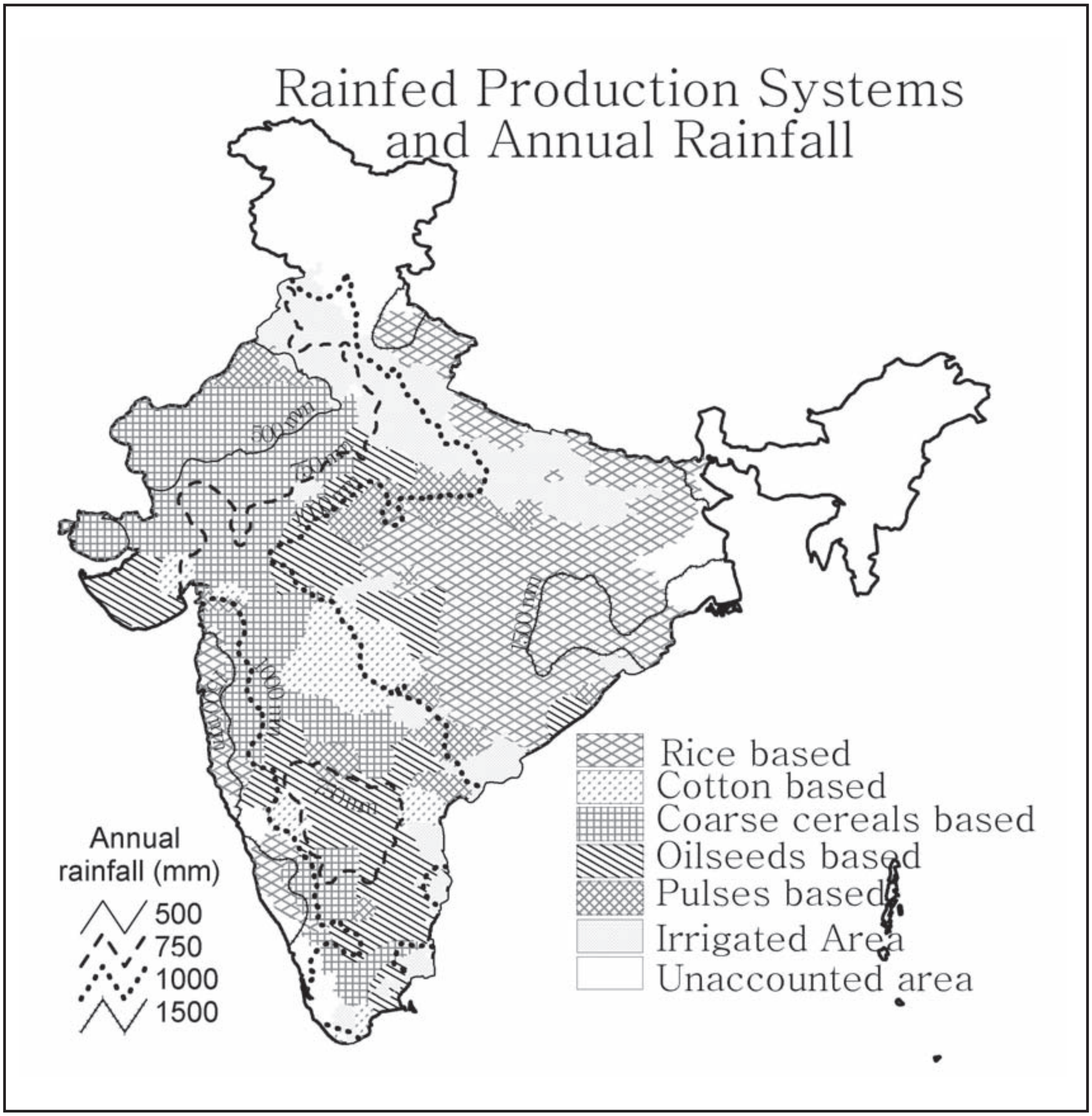


Fig.1. Distribution of rainfed crop based production systems under different rainfall zones

planting dates in the face of variable rainfall patterns. But despite their advantages, traditional drought management strategies also have associated opportunity costs, and they are ineffective for the poor. By diversifying their crops to reduce risk, farmers are less able to exploit their most profitable alternatives. In effect, farmers sacrifice potentially higher income on varieties that are more drought tolerant but less productive, and are often less willing to use or invest in modern inputs, improved seeds and fertilizers, that could increase average profitability but lead to loss of capital investment if rainfall is unfavorable. These opportunity costs can especially be costly to the poor because their average incomes are already so low to begin with.

3. Drought Definition

Drought occurs in high as well as low rainfall areas. Farmers term drought as deficient rainfall, lack of moisture or a dry spell resulting in low crop yields including crop failure. They realize that seasonal variations in precipitation and temperature are much more important in farming than annual averages. Regardless of variability in perspective, it is clear that drought is a normal feature of climate and its recurrence is inevitable. The American Heritage dictionary (1976) defined drought as a long period with no rain especially during planting season. The Random House dictionary (1969) defined it as an extended period of dry weather, especially one injurious to crops. Drought is a condition relative to some long-term average condition of balance between rainfall and evapotranspiration in a particular area, a condition often perceived as normal. Yet average rainfall does not provide an adequate statistical measure of rainfall characteristics in a given region, especially in the drier areas.

Agricultural drought is usually defined as a period when insufficient water is available to support the normal activities of a crop over a fairly normal long period of time of a fortnight or more depending on stage of crop. Drought is distinguished from aridity and it may be expected that both very wet and very dry regions experience drought. From an agricultural standpoint, a drought indicator should record crop management on the phenological drought sensitivity. Weather technology should be collineated. Thus, the partition between weather effect on yields and technology should be diffused. Emphasis should be placed on identifying periods within a given growing season when drought related weather conditions have greatest effect like yield altering impacts and crops. An operational definition would be one that compares daily precipitation values to evapotranspiration rates to determine the rate of soil moisture diffusion and express these relationships in terms of drought effects on plant behaviour at various stages of crop development. Thus, intensity of drought is a ratio of actual evapotranspiration (AET) to potential evapotranspiration (PET) during the growing season.

AET/PET	Intensity of Drought
0.00 – 0.24	Severe
0.25 – 0.49	Moderate
0.50 – 0.74	Mild
0.75 – 0.99	Low
1.00	Nil

These scales of intensity of drought are used later to describe the management practices in arid, semi-arid and sub-humid regions

4. Drought Management

The general belief about the natural disasters is that they are inevitable, unavoidable and unmanageable. A change in this outlook based on scientific approach would help in mitigating the affects of drought. The complexity in defining the magnitude of agricultural drought is due to diversity in crops grown, spatial variability in soil, temporal and spatial variability of rainfall, delay in timely operations in agriculture, multiplicity in crop management practices and others. More seasoned and progressive farmers feel that the changes in farming technology may greatly change the nature of future drought impacts, but they do not feel that drought has been overcome.

There is ample scientific evidence to suggest that productivity of rainfed regions can be enhanced significantly on a sustainable basis, provided the two basic natural resources, soil and rainwater, are managed in a judicious manner. Over the last several decades, researchers have concentrated on methods of increasing crop production under dryland conditions in order to mitigate drought effects at farm level. Simple easily implementable practices were developed for doubling the yields even in dry years over farmers' practices. This improved crop husbandry insulates crops against mild stress and helps increase yield stability. To meet the weather aberrations, alternate crop strategies to the mid season correction and crop life saving techniques forms important components. Above all, drought planning must be viewed as a dynamic process requiring continued attention. Drought can be tackled in dual manner by –

- managing drought based on intensity in a season, and
- drought amelioration on permanent basis

4.1 Management of drought based on intensity in a season

Water stress in plants, particularly in post-rainy season and during dry spells in rainy season is a common phenomenon. It is characterized by decrease in osmotic and total water potential, accompanied by loss of turgor, reduced diffusion of carbon dioxide into plant leaves, and therefore, reduction in photosynthesis and decrease in growth. However, the plant response to water stress is governed by soil, plant, and environmental factors. The degree and duration of water stress and the growth stage, at which it occurs, considerably modify the crop response.

Major part of the country's rainfed agriculture is fed by the Southwest monsoon. Hence, its onset, continuity, intensity, volume and withdrawal patterns have a tremendous influence on the agricultural production. High intensity rains produce volumes of water beyond the intake capacity of the soil and may leave the soil dry at lower depths. With intermittent long dry spells this situation affects rainfed crops adversely, even in areas with moderate to high rainfall. Thus improving soil surface conditions to increase infiltration and improving water holding capacity are two basic requirements in drylands. The interterrace management practices for *in situ* conservation of rainwater and ensuring its uniform distribution within the field and throughout the crop growth period assume paramount importance in dryland crop production. Extensive research efforts on rainwater management from early twentieth century rationalized and intensified during the past thirty years have resulted in identification of several do-able technologies for moisture conservation. However, the choice of the most appropriate practice is a function of the soil type, rainfall characteristics, and topographic features. Drought management strategy should involve integrating models of the adjustment process.

4.1.1 Types of agricultural droughts

Drought is a climatic anomaly characterized by deficient supply of moisture in rooting zone of soil resulting either from sub-normal rainfall, erratic rainfall distribution, higher water need or a combination of all the three factors. Crop production in rainfed areas is generally affected by chronic (permanent) drought (Southwest monsoon for *kharif* region and Northeast monsoon for *rabi* region with low rainfall), ephemeral drought (occurring in early, June-July; mid, July-August; and terminal, September-early October periods during crop growth in Southwest monsoon season), and apparent (Southwest monsoon with high rainfall) drought. Permanent drought usually had a high frequency of occurring once in 2 to 5 years while drought in ephemeral region will be once in 5 to 10 years and once in 10 to 20 years in apparent conditions. The details on climate, soil orders, season crop phase, etc. are described (Fig.2).

4.1.2 Management chronic droughts in arid regions

A drought prone area is defined as one with the probability of a drought year is greater than 20%. A chronic drought prone area has a possibility of 40%. A drought year occurs with less than 75% of the normal rainfall received. Chronic droughts occur in the arid and dry semi-arid region. In arid region of Western plains, Kachchh and part of Kathiawar peninsular hot eco region, the length of growing period is mostly less than 60 days. Under assured conditions with deep loamy soils the length of growing period is 60 to 90 days in the hard hyper sandy desert soil. The crops are mostly grown in the deep loamy soils. The chronic drought also occurs in the Southwest and Northeast transitional

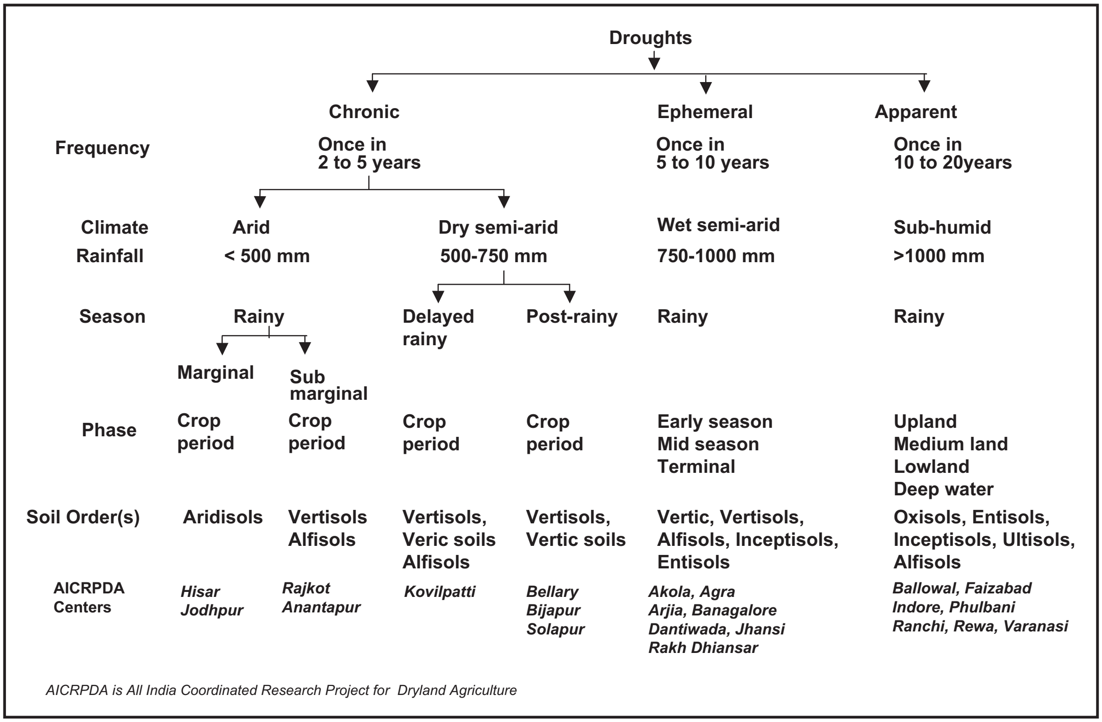


Fig.2. Types of Agricultural Droughts

zone of rainfall in Karnataka Plateau (Rayalaseema is included) with alfisols having low to medium available water capacity and 60-90 days of length of growing period. In dry semi-arid region of Karnataka Plateau, the crops are taken in the *rabi* season under receding soil moisture. Permanent/ chronic droughts are common in extreme arid areas where rainfall and stored soil moisture are inadequate to meet the water requirements of crops during most of the years and assured growing period is just only 6 to 7 weeks. Though this region is more suitable for desert grasses, crops are grown for subsistence in these regions in spite of insufficient rainfall. These regions are thus characterized as chronic drought or permanent prone areas. Apart form these types of droughts; in the low to medium rainfall regions, the rainfall quantum and distribution may be sufficient to support a low water requirement crop but not a crop with higher water requirements. When such a crop is introduced for economic reasons, the rainfall pattern may not adequately meet the demands. As a consequence, clear drought conditions are seen in some areas due to mismatching of the cropping pattern in relation to rainfall/moisture availability patterns. An example is growing maize or groundnut in this region. The crops that can be grown, required soil and water conservations measures, weed management and harvesting for hyper arid and arid areas under various moisture available indices are given in Fig.3.

Season	Highly erratic onset of season with low rainfall							
Climate	Arid region with length of growing period of about 70 days and more in rainy season							
Land	Marginal				Sub-marginal			
Season	Southwest monsoon with low rainfall ~ 300 mm				Southwest and northeast transitional zone with rainfall ~ 500 mm			
Production system	Coarse cereals				Oilseeds and coarse cereals			
Drought Intensity	Low	Mild	Moderate	Severe	Low	Mild	Moderate	Severe
Land preparation	Almost absent	Summer tillage	Summer tillage	Absent	Almost absent	Summer tillage	Summer tillage	Absent
Crops based on soil depth/ available water capacity	Pearl millet Moth beans Cluster beans Minor pulses	Pearl millet Moth beans Cluster beans Minor pulses	Pearl millet Moth beans Cluster beans Minor pulses	Sowing will be a problem	Groundnut (late sowing preferred) Castor Pearl millet	Groundnut Castor Pearl millet	Groundnut Castor Pearl millet	Groundnut Castor Pearl millet
Soil and water conservation	Ridges and Furrows Deep Ploughing once 2-3 years	Inter plot water harvesting Ridges and furrows Deep ploughing once in 2-3 years	Inter plot water harvesting Ridges and furrows Mulches	Blading	Ridges and furrows Dead furrow	Ridges and furrows Dead furrow	Ridges and furrows Dead furrow	Blading
Plant protection	Blade harrowing Intra row weeding	Blade harrowing Intra row weeding	Blade Harrowing Locust control	Locust control	Blade harrowing Intra row weeding Leaf spot	Blade harrowing Intra row weeding Leafspot, Bud/stem necrosis	Blade harrowing Bud/stem necrosis	
Harvesting	Grain and fodder	Grain and fodder	Fodder/grain		Grain	Groundnut digging problem		

Fig.3. Management of chronic droughts in dry semi-arid region

4.1.3 Management of drought under receding moisture condition in dry semi-arid regions

The *rabi* region occurs mostly in hot semi-arid Deccan Plateau, the available water capacity is medium to high with length of growing period varying from 90 to 180 days based on the clay content of soils. In the late *kharif* season, semi-arid vertisols of Tamilnadu uplands and Deccan Plateau, the available water capacity varies from low to medium. The length of growing period varies from 90-150 days depending on soil depth and clay content. In the dry semi-arid region of late *kharif* and *rabi* vertisols, the crop, soil water conservation measures, pest management and harvesting are presented in Fig.4 based on available water capacity of the profiles.

4.1.4 Management of ephemeral droughts in wet semi-arid regions

Ephemeral drought is usually limited to wet semi-arid regions during Southwest monsoon. The regions covered include Northern plains and central high lands including Aravallis,

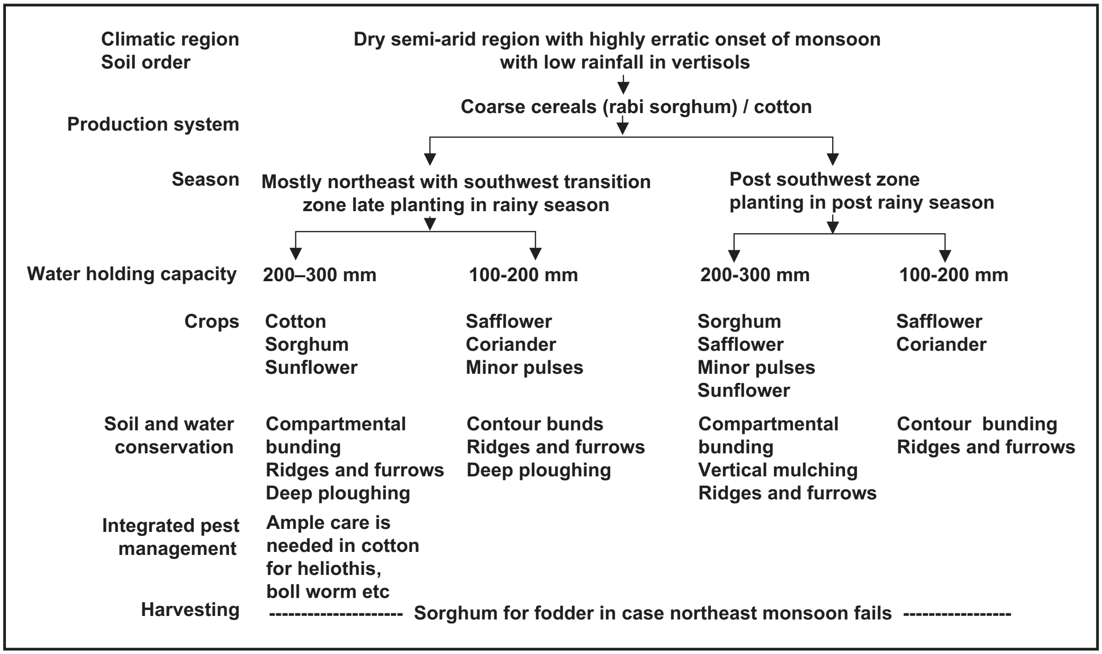


Fig.4. Management of drought under receding moisture condition in dry semi-arid region

Malwa regions, Gujarat Plains, Kathiawar Peninsular, Deccan Plateau and Eastern Ghats. The available water capacity is varying between 50 to 150 mm in lighter red soils and 100-200 mm in black soils, except in few cases in the lighter soils, the length of growing period is 90-120 days whereas in medium to deep black soils, the length of growing period is 150-180 days. In the wet semi-arid region with 750-1000 mm annual rainfall, rainfall mostly (~85%) occurring during June to October months. The drought occurs ephemerally in early season (seeding stage), mid season (grand growth stage) or termination (flowering to grain filling stage) of season. The effect of drought on productivity increases from early to end of season. The contingency crop plans for various weather aberrations are described in Annexure-I.

4.1.4.1 Early season drought

Early season drought generally occurs either due to delayed onset of monsoon or due to prolonged dry spell soon after the onset of rainy season. This may at times result in seedling mortality needing re-sowing or may result in poor crop(s) stand and seedling growth. Further, the duration of the water availability for crop growth gets reduced due to the delayed start and the crops suffer from acute shortage of water during reproductive stage due to early withdrawal of monsoon. Therefore, for characterization of early season drought, information on optimum sowing period for different crops/varieties, quantum of initial rainfall spell expected and its ability to wet the soil profile enough to meet the crop water requirements for better germination and establishment is essential.

The effect of early season drought is less on the crop, because during this period sowing is carried out. Various operations carried out are primary tillage, sowing, fertilizer application and intercultural operations. On plant emergence and establishment, the effect of drought in first 2 to 4 weeks may affect initial vigour but may not have dire consequences on yield. In case of late onset of monsoon by 3 to 4 weeks, contingency plans are needed. Management practices are described in Fig. 5.

Climate	**Wet semi-arid region southwest monsoon**				
Phenophase	**Seedling phase**				
Production System	**Coarse cereals/ oilseeds/ pulses**				
Season onset	**On-time**				**Delayed**
Drought Intensity	**Low**	**Mild**	**Moderate**	**Severe**	**Severe**
Primary tillage	**Soil workability problem with high clay**	**Some times clodding**	**Delayed, shallow tillage, loss of soil moisture**	**Shallow blading is only possible**	**Primary tillage put off**
Crops and cropping systems	**No restriction on crops and cropping systems, Optimum population maintenance by uprooting/ thinning Second crop establishment may be a problem**	**No restriction on crops and cropping systems, optimum population Maintenance by gap filling and/ or transplanting Seqence crop Intercropping**	**Selection of crops tailored to season like millets/ oilseeds/ pulses and Intercrops Germination may be affected by Crusting/ reseeding/ gap filling, comeup irrigation**	**Dried crop may be turned in, dry seeding of short duration bold seeded crops, avoid Intercropping with long duration crops mixed cropping, contingency plans, Gap filling**	**Till and sow method, contingency plans, mixed cropping to overcome crusting, no long duration crops**
Integrated nutrient management	**Half N dose + full P and others + Half N as legume/ residues Incorporate/ mulch. Need based soil amendments**	**Half N dose+ full P and others + Half N as legume organics as mulches**	**Half N dose+ full P and others +Half N as legume organics as mulches**	**Apply fertilizer top dressing, Half N as organic as mulches**	**Apply fertilizer top dressing, half N as organic as mulches**
Interculture	**Repetitive blade harrowing, Intra-row weeding, post-emergence weedicides**	**Few times blade harrowing, Intra-row weeding, post-emergence weedicide, Dead furrows**	**Blade harrowing, Intra-row weeding, Dead furrows**	**Blading**	**Blading**

Fig.5. Ephemeral drought in early season in wet semi-arid region

4.1.4.2 Mid season drought

Mid season drought occurs due to inadequate soil moisture availability between two successive rainfall events during the crop-growing period. Its effect varies with the crop growth stage and the duration and intensity of the drought spell. Stunted growth takes place if it occurs at vegetative phase and if it occurs at flowering or early reproductive stage it will have an adverse effect on ultimate crop yield. Management of rainwater, especially *in situ* conservation of moisture, is a vital component of dryland crop management practices. In agricultural lands with 1-3% slopes, runoff is about 25-35% when the rainfall is in the range of 700-800 mm. Though a lot of emphasis has been laid on soil and moisture conservation, the efforts mainly concentrated on construction of various types of bunds across the slope. This helped in controlling erosion and soil loss rather than achieving uniform moisture distribution. The research results have indicated that bunding increased the crop yields by a mere 6% while a simple inter-terrace management such as contour cultivation that helped in uniform distribution of moisture, raised crop yields by 15-20%, the impact being more pronounced in years of scanty rainfall.

During mid season, plant protection, top dressing of fertilizer, interculture, supplemental irrigation are the usual practices, in case of severity ratooning of few crops can be tried. In case the season is good, relay cropping is practiced (Fig. 6). In case of long dry spells, location specific contingency plans are needed.

Climatic zone — **Southwest monsoon in wet semi-arid region**
Phenophase — **Grand growth/ flowering phase**
Season — **Long dry spell(s) in middle of the season (August)**

Drought Intensity	Low	Mild	Moderate	Severe
Plant protection	High humidity conducive to pests, diseases and Weeds. Needs vigilance	Humidity conducive to pests, diseases etc. Needs care	Clear weather may not be conducive to white ants etc. Cautious protection	Dry weather is not conducive to pests build up. Protection may not be economic
Fertilizer top dressing	More N can be applied than recommended. Split N as many times as possible. Sprays or application of secondary and micronutrients/ incorporation organics for hidden hunger. Effectiveness is a needed consideration	Split N can be applied Hunger may not be expressed. Sprays or application of Secondary and micronutrients needed Mulch/ Incorporate organics	Cautious top dressing Sprays of B, K etc during stress	Top dressing may not be economic Sprays of B, K etc during stress
Soil water conservation	Ridges and furrows	Blade harrowing	Blade harrowing in case of need	Blade harrowing if possible. Reduction of green leaves
Supplemental irrigation	Not needed	May not be needed	Cautious application water 0.5 to 1.0 cm For millets and 2.5 to 5.0 cm for others	Based on availability of harvested water 0.5 to 1.0 cm for millets and 2.5 to 5.0 cm for others
Ratooning			Harvesting partly for fodder to permit ratoon crop	Harvesting for fodder to permit ratoon crop
Future plans	Relay cropping	Sequence crop Relay cropping	Ratoon cropping	

Fig.6. Management of ephemeral drought in mid season in wet semi-arid region

4.1.4.3 Terminal drought

During terminal period, plant protection (soil water conservation) interculture, supplemental irrigation, harvesting are the practices. Late season or terminal droughts occur as a result of early cessation of monsoon rains and it can be anticipated to occur with greater certainty during the years with late commencement or weak monsoon activity. Terminal droughts are more critical as the grain yield is strongly related to water availability during the reproductive stage. Further, these conditions are often associated with an increase in ambient temperatures leading to forced maturity. Fodder needs may be met from contingency plans. Management strategies of ephemeral drought in terminal season are described in Fig. 7.

Climatic zone	Southwest monsoon in wet semi-arid region
Phenophase	Reproductive phase
Season	Early cessation of monsoon (September)

Drought Intensity	Low	Mild	Moderate	Severe
Plant protection	High humidity conducive to molds and sucking pests in compact heads and diseases on leaves. Needs dusting	Humidity conducive to molds and sucking pests in compact heads Needs dusting	Clear weather may not be conducive to serious pests build up Cautious protection	Dry weather is not conducive to pests build up. Protection not needed
Foliar sprays	Not needed	Not needed	Cautious top dressing Sprays of B, K etc during stress	Sprays of B, K etc During stress
Soil water conservation	Not needed due to good canopy cover (Leaf area index ~ 4)	Not needed due to good canopy cover (Leaf area index ~ 3-4)	Blade harrowing in case of need	Blade harrowing if possible, reduction of transpiring leaves
Supplemental irrigation	Not needed	May not be needed Judicious application water 0.5 to 1.0 cm for millets and 2.5 to 5.0 cm for others once in furrows	Cautious furrow Application of water 0.5 to 1.0 cm for millets and 2.5 to 5.0 cm for others once	Based on availability of harvested water 0.5 to 1.0 cm for millets and 2.5 to 5.0 cm for others twice
Harvest	Harvest at physiological maturity to avoid damage by grain sucking insect	Better to harvest at physiological maturity to avoid damage by grain sucking insect	Harvesting partly for Fodder In case of grain Filling problem	Harvesting for fodder
Second crop	Relay cropping Sequence crop Establishment is difficult	Ratoon crop Relay cropping	Ratoon cropping	

Fig.7. Management of ephemeral terminal drought in wet semi-arid region

4.1.5 Management of apparent drought in sub-humid regions

Apparent drought occurs in sub-humid area with high rainfall with rainfed rice based production system in Northern plains, central high lands of Malwa and Bundelkhand, Eastern Plateau, Plains and Ghats region. The length of growing period is 150-180 days.

However, in deep loamy clays, the length of growing period is 210 days while in shallow soils, the length of growing period is 120-150 days. Soils have 100-200 mm medium water holding capacity. Rainfed rice in sub-humid regions is often subjected to such terminal droughts due to failure of September rains, which are crucial at the reproductive stage. The probabilities of intermittent dry spells of greater than 5 days duration in the areas are about 40 to 50% during September. Contingency plans are described based on toposequence. Management of apparent drought in dry to moist sub-humid region is described in Fig. 8. Livestock also forms an essential part of the production system.

Climatic zone	**South west monsoon with high rainfall >1000 mm**						
Phenophase	**Rainfed rice zone on toposequence, efffect of drought is severe**						
Season	**Rainy season**						
Toposequence	**Uplands**				**Medium and low lands Terrace (20 to 40 cm dyke)**		**Deep water (~ 1 m dyke)**
Drought Intensity	**Low**	**Mild**	**Moderate**	**Severe**	**Low**	**Mild**	**Low**
Crop(s)	**Rice**	**Rice, Maize Groundnut Finger millet Pigeonpea Minor pulses**	**Sorghum Maize Horsegram Pigeonpea Minor pulses**	**Horsegram**	**Rice Sequence cropping**	**Rice/ groundnut/ fingermillet/ maize**	**Rice**
Land preparation	**Ploughing**	**Ploughing**			**Puddling**	**Puddling**	
Planting	**Broadcasting**	**Seed drills**	**Ploughing and planting**	**Ploughing and broadcasting**	**Transplanting**	**Transplanting**	**Broad-casting**
Water mangement	**Bunded or unbunded**	**Bunded or unbunded**	**Bunded or unbunded**	**Bunded or unbunded**	**Bunded Drainage problem**	**Bunded Drainage problem**	**Bunded or unbunded without Drainage point**
Interculture	**Criss cross plowing for weeding and population control in rice**	**Criss cross plowing for weeding and population control in rice**	**Blade harrowing Ridges and furrows**	**Blade harrowing**	***Beushening/ biasi***	***Beushening/ biasi***	
Livestock	**Piggery**	**Piggery**	**Piggery**	**Piggery**	**Fisheries**	**Fisheries**	**Fisheries Cattle/Pigs**
Plant protection	**Rice based**	**Rice based**			**Rice based**	**Crop based**	
Second crop (*Piara, Utera*)	**--------------------------------------- Horsegram ------------------------**				**Wheat/ chickpea pre sowing/ critical irrigation**	**Irrigated wheat, chickpea Minor pulses relay cropping**	**Low land winter rice Summer irrigated rice**

Fig.8. Management of apparent drought in sub-humid region

More than moderate drought intensity in medium and low lands and more than mild drought intensity in case of deep water rice, leads to non-planting of rice. Change in land use towards rice with less water requirement may be adopted. This needs advance weather prediction to farmers.

4.2 Drought amelioration on permanent basis

Any production system as a technology has different components referred to as techniques. The system, by and large, would be an improvement over the existing traditional or indigenous system. In either case, the system would be basically subsistent in nature and the productivity must be improved. Apart from moisture stress to corps, mismanagement of rainwater also entails serious land degradation converting vast areas across the country into wastelands. It is a paradox that rainwater, the most vital resource for crop production in drylands, becomes a dominant factor (as runoff) of land degradation to the extent that productive lands are converted into uncultivable wastelands.

4.2.1 Land capability based productive farming systems

Tailored cropping systems that Agro Ecological zones should be followed to minimize adverse affects on the total land productivity. Contingency crop Plans should be available along with inputs and generated market. Optimum fertilizer use may help guard against drought by encouraging deep root system and utilizing soil water efficiently. Cropping system selection based up on land capability, rainfall and soil is described (Fig.9). Land capability and system based fertilizer management practices are given in Annexure II for building soil resilience and quality. The steps in enhancing the crop productivity in rainfed areas are –

- Timely sowing of seed in rows in the moist zone
- Use of proper seed rate to achieve adequate plant stands
- Timely weeding creating soil mulch so that soil moisture is not lost through evaporation.
- Use of seed-cum-ferti-drills for good plant stand
- Row placing of moderate levels of fertilizer (basal as well as top dressing) not on blanket basis, but on a need base
- Use of complex fertilizers depending on the economic status of the farmer
- Intercropping in areas with >650 mm rainfall as a step towards risk distribution
- Use of a legume as a component in the cropping system, either in rotation, sequence, or intercropping

Alternate land use systems (Agroforestry, Silviculture and pasture) are identified for drought prone regions (Fig.9) based on rainfall, land capability and soil order. Some steps in enhancing productivity are –

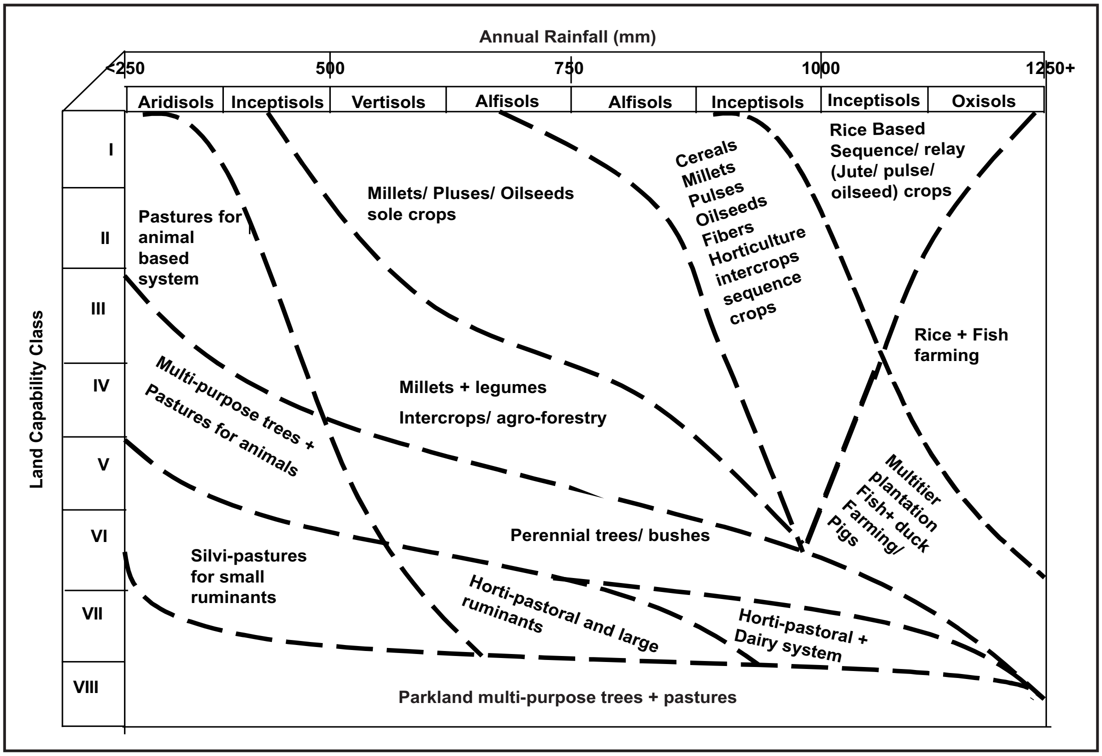


Fig.9. Productive farming systems matrix in rainfed agriculture

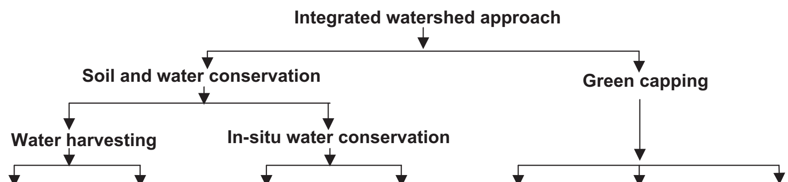
- The commons may be divided into small plots of 5-10 ha and provided on long lease of about 19 years to the user groups.
- Adopt any of the system, such as fruit trees, silvipastures, multipurpose trees, or even pastures, a combination.
- Maximum number of trees per hectare may be limited by quantum of annual rainfall (product of rainfall, m and area, m^2) divided by volume of water one full grown tree transpires annually (a product of canopy area, surface area in m^2, and potential evapotranspiration in m per annum).
- Rejuvenation by social fencing of improved plant species. Improved variety or new plant species suitable for the ecosystem.
- In tree farming the general cleanliness of the area is lost thus encouraging new diseases and pests. Hence, it is important to carry out weeding and make basins for the trees and furrows for *in situ* rainwater harvesting in the case of shrubs, grasses, and fodder legumes.
- Encourage cultivation of medicinal and other industrial plants in the commons as new avenues for income generation.

4.2.2 Land capability based soil and water conservation measures

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. The prioritized steps involved in resource conservation are –

- Use of practices based on the existing traditional systems
- Encourage farmers to adopt contour farming
- Adopt contour bunding in new areas being brought under plough and with large farm plots
- Strengthen the existing bunds across the slope and provide weirs
- In the case of drainage line treatment, start from the ridge line to the bottom
- The traditional loose boulder structures as well as grassing may be adopted
- Later, gully plugging and construction of small check dams on the drainage line are carried out
- After bunding and provision of waterway, grow dual-purpose plant species on the bunds
- Provide small cross section bunds with a small furrow on the upper side, preferably with a heavy country plough or mould board plough
- The watercourse is covered with vegetation, preferably before other treatments are superimposed

Conservation is incomplete without smooth disposal of surplus water and development of inter-terraced area. Hence, the present emphasis is on replacing large section bunds with small section bunds to achieve uniform distribution of moisture. The principle behind the recommendation is to reduce the runoff by increasing the opportunity time through modifying land configuration and improving soil properties (Fig. 10). The red and black soils, two major soil types of the rainfed areas, have distinctly different characteristics and hence, differ in their needs of moisture conservation methods. The red soils (light soils) have higher infiltration rate but low moisture-holding capacity while, the black soils (heavy soils) have low organic matter and suffer from infiltration rate because of higher expansion on wetting. Climate and soil are the two dominant factors in deciding whether or not runoff farming/water harvesting system will be possible and sensible. The hyper arid zone ($P/PET < 0.03$, where P is precipitation and PET is potential evapo-transpiration) is too dry for viable runoff farming, while sub humid zone (P/PET 0.5-0.75) will be too wet. The runoff-farming zone is primarily situated in the arid to semi-arid zones.



Production system	Indigenous technology	Exogeneous technology	Indigenous technology	Modern technology	Annual covers	Erosion filters	Perennial covers
<500 mm arid coarse cereals, oilseeds and pulses Sheep, goat, buffaloes	*Khadins* *Tankas*	100 to 200 m^3 ponds, Crop life saving irrigation	Field bunds	Inter-plot water harvesting Dead furrows	Sole crop to intercrops and mixed crops	*Lasirus sindicus* *Panicum turgidum*	Wind breaks Dune stabilization *L Sindicus+Khajri* Parkland Horticulture Silvipasture Trees on bunds Economic shrubs
500-1000 mm *Semi-arid* coarse cereals, Cotton, Oilseeds and Pulses, Buffaloes, Goats,Sheep, cattle	Tanks Field bunds	200- 1000 m^3 ponds Supplemental irrigation	Field bunds	Contour bunds Compartment bunding Zingg terracing Broad bed and furrow Vertical mulching	Intercrops sole rabi crop Sequence crops	Red soil *Cenchrus setigerus* *C. ciliaris* *Chry sopogon fulvus* Black soils *Iselemalaxum* *Panicum maximum* *Dichanthium annulatum*	Alley cropping Agri-horticulture Plantations Economic shrubs Home remedies Medicinal aromatic plants
>1000 mm *Sub-humid* Rainfed rice, coarse cereals, Pulses, Buffaloes,cattle, pigs,ducks	Submergence *Bundhies,Haveli,* Terraces, *Tals*, *Choes*, Deep water paddy, Low and mediumLands, Un-bunded upland	>1000 m^3 ponds for alternate land uses Streamlets Amelioration of drainage by summer irrigation	Field bunds Leveling	Raised and sunken beds Bunding of uplands Drainage channels	Rice cropping Piara/relay cropping Intercrops Sequence cropping Paddy fallows	Forestry	Timber/ Fiber High density horticulture

Fig.10. Drought proofing measures in arid, semi-arid and sub-humid regions

A significant quantity of rainwater, 160 mha-m as surface flow is available for harvesting, which through small interventions, could be efficiently used for combating drought-related crop failures. Estimates reveal that areas receiving up to 1000 mm annual precipitation hold a potential to add 6.3 mha-m water equivalent through runoff. The steps involved in rainwater harvesting are –

- Use of traditional systems of rainwater harvesting (eg. Tanks, *Talabs, Ahars, Zabo* system). Construct suitable conduits.
- Other rainwater harvesting systems meant for recession cropping should also receive equal attention (eg. *Khadin, Ad-band, Bandh*).
- Non-functional systems should be repaired immediately. Refinements of indigenous water harvesting system may be attempted (Annexure-III).
- Silted tanks could be converted into percolation tanks, particularly in light soils.

- Rainwater harvesting for recession cropping is unique and has some location specificities including socio economic considerations. These must be considered first before going in for their imposition in new areas.
- The bandh system (otherwise known as Haveli system) can be transformed wherever possible to two cropping system instead of *rabi* (post rainy season) cropping only.
- Ponds or embankments should be constructed. A pond of 250 m^3/ha catchment is recommended.
- Ponds are essential primarily for horticulture and multipurpose trees in Class V and above lands.
- Even small ponds can be dug and each plastered as a cistern (50 m^3). Water can be harvested or transported into them in the arid eco system. Such water should be treated as of immense value for sustaining tree vegetation during the post rainy periods.
- The large embankments are costly and need full participation by the Government agencies.
- Structures such as percolation tanks meant for ground water recharge are expensive and should be constructed only when there is enough funds left after the normal treatment of the watershed. All the resource conservation measures and other water harvesting systems enhance groundwater recharge.
- When these structures are built, there will be more water available in the region. This will trigger more wells including bore wells.
- Consider the wells existing in the area and then calculate the potential water supply as well as the increased supply through the various field and drainage line treatments.
- Follow strict water bundgeting for sustainable use of the harvested rainwater.
- Allow only low duty crops. Avoid sugarcane, rice, and wheat. Encourage pulses and oilseeds.
- Introduce horticulture in class V and above lands. Provide irrigation cover for the first two yeas. Do not irrigate the fruit trees without providing suitable basins.

Detailed soil and water conservation measures to be carried out by farmer/community based on land capability and rainfall are presented in Annexure IV.

5. Epilogue

Unabated land degradation due to nutrient mining by crops combined with topsoil loss by water erosion and climatic change towards adverse conditions are the twin problems affecting the future of dryland agriculture. In this connection, an early action is to be taken by controlling erosion, replenishing the soil with high biomass on continuous basis for revitalizing the various soil processes and congenial microenvironment creation. Invariably this will improve the soil resilience, quality and mitigates the drought affect. The practice that is needed is the resource conservation and utilization based template created by using perennial, semi-perennial and annual plants. This knits the farmers to the land and generates employment through out the year. Use of cash returning species will improve the socio-economic conditions of the farmers. Agroforestry is relatively new name given to an approach to cultivation, which has been used by many people all over the world, in many different ways. It is a collective name for land use systems in which woody perennials are grown in association with herbaceous plants (crop, pastures) or livestock, in a spatial arrangement, a rotation, or both. There are usually both ecological and economic interactions between the tree and other components of the system. The agroforestry model is unique as it focuses on assisting farmers in creating a situation where they are managing their own natural resources including livestock in a sustainable productive way, and making them less dependent on outside labour and forest areas. To prevent runoff and soil erosion and to meet all the requirements in terms of fodder resources and soil cover, efforts must be made to obtain them from integrated farming system only. The cropping system must permit limited grazing. Sufficient loppings should be available from the farmstead. Micro level farming systems are practicable only in rainfed lands due to resilience in adoption of diversification from crop through tree to animal. This promises micro-environment change for coping the adverse effects of drought and coping over a long time.

Annexure I

Contingency cropping plans for different drought types based on climate and soil orders

Recommendation	Crop Plan						
Domain	**June second fortnight to July first fortnight**	**Second fortnight of July**	**First fortnight of August**	**Second fortnight of August**	**September first fortnight**	**September second fortnight to October first fortnight**	**October second fortnight to November first fortnight**
1	2	3	4	5	6	7	8
1.1 Chronic drought in arid region in marginal soils with < 500 mm							
Hisar, Bhiwani, Sirsa, Mahendragarh, Gurgaon and part of Rohtak district of Haryana in marginal hot typic arid aridisols	Pearlmillet Cluster bean Greengram	Short duration crops Pearlmillet (HHB-67) Greengram (Asha) Blackgram (T-9) Cowpea (Charodi) Clusterbeans (HG 365)	Nursery of Pearlmillet (HHB 67) nursery may be kept ready for transplanting. Crops Fodder	Toria with supplemental irrigation Rains received after mid of August may be conserved for *rabi* sowing.	Clusterbean Cowpea	Chickpea Taramira Rapeseed	Mustard Taramira Use water in farm ponds, tanks and *tankas (Kund)* for drip and sprinkler irrigation for the horticulture, vegetables and high value crops.
1.2 Chronic drought in arid region in sub marginal soils with 500-750 mm							
Rajkot, Surendranagar, Jamnagar, parts of Junagarh, Bhavanagar and Amreli districts of Gujarat in hot arid vertisols	Sorghum, Pearlmillet, Groundnut, Castor, Cotton	Erect groundnut (GG-2, GG-5, GG-7) Sesame (G. Til-1, G. Til-2) Pearlmillet (GHB-235 GHB-316, GHB-558) Greengram (K-851, GM-4) Blackgram (T-9) Pigeonpea (ICPL-87, GT-101)	Blackgram (T-9), Forage maize/ sorghum (Gundri, GFS-5), Castor (GAUCH-1) Sesame (Purva-1)	Forage maize Sorghum (Gundri, GFS-5) Sesame (Purva-1)	Usually no rainfed crop is sown		
Anantapur, Kurnool, and Chittoor districts of Andhra Pradesh in sub marginal arid Alfisols	Sorghum Pigeonpea Castor *Mesta* Cowpea Groundnut	Groundnut (Vemana, TMV 2) + Pigeonpea, Pigeonpea (Palnadu)	Groundnut (TMV 2, ICGV 91114)	Pearlmillet (ICTP 8203, ICMV 221) Greengram (MGG 295, MGG 407, PDM 54) Dual purpose Sorghum (M 35-1-1, NTJ-1, 2, 3 and 4) Horsegram (AK 21, Marukulthi and Local)	Cowpea	Cowpea, Horsegram	Usually no crop in rainfed region is sown

1	2	3	4	5	6	7	8
1.3 Chronic drought in dry semi - arid region with 500-750 mm (late rainy season to post-rainy season)							
Maduari, Ramanthapuram and Tirunalveli districts of Tamil Nadu in hot moist semi-arid alfisols/ vertisols	Onset of monsoon is from September				Cotton Sorghum Pearlmillet Setaria Cotton Chillies Medium-duration pulses, Flowers, vegetables	First fortnight of Grain sorghum Third week of Chilies Fourth week *Panicum miliaceum* Chickpea Short-duration pulses Safflower Setaria Coriander Pearlmillet	First week *Karunganni* Cotton Sunflower and Sesamum sowings can be done during first week of November Senna No rainfed crop sowing beyond third week of November
1.4 Chronic drought in dry semi – arid region with 500-750 mm (post-rainy season)							
Parts of Chellakera, Chitradurga, Bellary, Raichur districts of Karanataka, parts of Anantapur, Kurnool and Mahaboobnagar districts of Andhra Pradesh (black soils) in hot arid vertisols	Sorghum Pearlmillet	Ratooning of pearlmillet Sorghum Groundnut in red soils	If pulses and oil seeds are sown and failed, greengram followed by *rabi* sorghum in medium black soils, Sunflower (Moren, KBSH-1, Mayhco-17) Pigeonpea re-sowing if failed completely horsegram sowing in red soils Chilli transplanting Onion+ Chilli	Sunflower sowing if groundnut failed. Any pulses or cereals failed. Pigeonpea sowing at close spacing (45x30 cm) Onion + chilli sowing / transplanting.	Safflower, R*abi* sorghum in deep black soils, *Dolichos lab lab*	Sorghum Chickpea Safflower Lima Bean *Dolichoslab lab*	Sorghum (M35-1 for fodder) Coriander Chickpea
Bijapur and Gulbarga districts, parts of Belgaum, Linguagur of Raichur district of Karanataka and southern parts of Maharashtra in hot semi-arid vertisols	Greengram Blackgram Pigeonpea Pearlmillt	Groundnut (spreading) Hybrid pearlmillet Sunflower and Setaria in *kharif* areas pure pigeonpea/ cowpea/ horsegram in light soils	Cotton in middle of August. Early sowing of cotton is advantageous Grow herbaceum cottons in place of hirsutums Sunflower Pigeonpea, castor and setaria in light soils. Pigeonpea in medium to deep black soils	In medium to deep black soils, on contour bunds Castor Relay cotton in groundnut in medium black soils.	Early sowing is more beneficial. Cotton (Bhagya/Laxmi) before first fortnight of September If rains are not received seeding of sunflower, *rabi* sorghum, chickpea with 1.5 times the normal seed rate. Sorghum, Sunflower (after first dekad of September),	Sorghum, chickpea safflower (before September) *Rabi* sorghum upto first fortnight of October *Rabi* sorghum + chickpea (2:1), *rabi* sorghum and Chickpea as mixed crops Chickpea and safflower (4:2 or 3:1). Wider row spacing or paired rows helps in moisture conservation especially during drought	Fodder crops

1	2	3	4	5	6	7	8
Solapur, Bid, Osmanbad, Ahmednagar, parts of Satara and Latur, Sangli districts of Maharashtra region in hot dry semi-arid vertic / vertisols	Pearlmillet Pigeonpea Greengram Blackgram Cowpea Kidney bean Horsegram Groundnut Sesame	Sunflower Pigeonpea Horsegram Setaria Castor Pearlmillet Sunflower + Pigeonpea (2:1) Pearlmillet + horsegram (2:1) Pigeonpea + clusterbean (1:2) Castor + clusterbean (1:2)	Sunflower Pigeonpea Castor Sunflower + pigeonpea (2:1)	Sunflower Pigeonpea Castor Sunflower + pigeonpea (2:1) Sorghum for fodder	Sunflower Sorghum Greengram Blackgram Mixtures of *rabi* sorghum + chickpea + safflower	Sorghum Safflower Chickpea	Sorghum (fodder) Chickpea Safflower
Ephemeral							
2.1 Ephemeral drought in wet semi - arid region with 500-750 mm (rainy season)							
Akola, parts of Amravati, Wardha, Yeotmal, Parbhan, Buldana and Khandesh districts of Maharashtra and parts of Adilabad of Andhra Pradesh in hot moist semi arid vertic/ vertisols	Pearlmillet (Shradha, Sabari, ICP 8203) Cowpea Greengram Blackgram Cowpea Sorghum	Pigeonpea (Asha, DSMR 736, BJMR 853) Pearlmillet (Shradha, Sabari, ICP 8203) Maize (AMC 1) Sunflower (PKV JF9, KBSH-1, Morden)	Pigeonpea (Asha, DSMR 736, BJMR 853) Pearlmillet (Shradha, Sabari, ICP 8203), Maize (AMC 1) Sunflower (PKV JF9, KBSH-1, Morden) Castor (AKC 1 GAUCH 1, GAUCH 2)	Pigeonpea Castor Fallow the land for *rabi* safflower to be sown during last week of September.	Safflower + Chickpea mix Safflower (No 7) may be sown after sorghum till first fortnight of October.	Safflower Chickpea	Chickpea
Agra, Mathura, Aligarh, Bulandshahar, Meerut, Etah, Mainpuri and West part of Muzaffarnagar district in hot semi arid inceptisols.	Pearlmillet Blackgram Greengram Pigeonpea Groundnut	Pearlmillet Clusterbeans Greengram Blackgram Pigeonpea of short duration	Transplanted pearlmillet Clusterbeans Greengram Cowpea	Clusterbeans Cowpea	—	Mustard Barley Chickpea Safflower	—

1	2	3	4	5	6	7	8
Bhilwara, Tonk, Dungarpur, Ajmer districts and parts of Bundi, Chittaurgarh, Rajasamand in hot dry semi-arid inceptisols/ aridisols	Pigeonpea Cowpea	Sesame (RT-46) Greengram (K-851 & RMG-62) Sorghum (Fodder) Cowpea (Fodder) (Raj Chari-1 & 2, C-152) No sowing of cereals Only short duration pulses and oil seeds or fodder crops should be sown. Soil mulching and interculture to conserve soil moisture is beneficial.	Sesame (RT-125) Greengram (RMG-62) Sorghum (fodder) (Raj Chari-1) (Single cut) Soil water conservation measures for *in situ* management & runoff harvest for recycling during later part of crop season.	Sorghum (Fodder) (Raj Chari-1) Toria (TL-15) Tarmaira (T-27) Rain received after first fortnight of August should be conserved for early *rabi* seeding of toria / taramira during first week of September. Any heavy downpour occurs, harvest the water for pre-sowing supplemental irrigation to *rabi* crops.	Greengram Blackgram Cowpea	Greengram Blackgram Cowpea	Chickpea Safflower Mustard Barley
Bangalore and Kolar districts and eastern parts of Tumkur districts of Karnataka in moist semi-arid deep alfisols	Groundnut Maize Fingermillet	Sowing of long duration varieties like Indaf-8, L-5 and MR-1 (up to third week of July) Transplanting of long duration varieties (Indaf-8, L-5 and MR-1) of fingermillet sown in the nursery during last week of July. Sowing of medium duration varieties (GPU-28/ HR-911/PR-202) in the nursery or directly for the main field. Fingermillet + pigeonpea (8:1) Fingermillet + fieldbean (8:1)	Sowing of medium duration fingermillet (GPU-28, HR-911 and PR-202) or transplanting the same from the nursery sown during second fortnight of July. Short duration fingermillet (GPU-26/Indaf-5) in the nursery for transplanting in the last week of August/ first week of September. Sunflower (KBSH-1, KBSH-41, KBSH-42, Morden) Niger (variety No.71).Cowpea	Transplanting of short duration fingermillet varieties (GPU-26/Indaf-5) sowing during first fortnight of August. Cowpea (KBC-1, KBC-2 Lolita) Horsegram (KBH-1/PHG-9) Transplanting of Chilli if protective irrigation facilities are available/ Fodder maize / fodder pearlmillet / fodder Sorghum (if available, protective irrigation to be given).	Cowpea Horsegram Safflower Fingermillet Transplanting Sunflower	—	—

1	2	3	4	5	6	7	8
		Minor millets like littlemillet and foxtail millet (upto third week of July). Groundnut Pigeonpea+groundnut (up to third of week of July).Sunflower (KBSH-1, KBSH-41, KBSH-42) Castor Soybean (KBSH-2). Transplanting of Chilli varieties (Arka Jobit, Ceylone selection, Chikkaballapur)	(KBC-1/KBC-2) Soybean (KBSH-2). Transplanting of Chilli varieties (Arka Lohit Ceylon selection) During first week of July Growing of fodder maize / pearlmillet/ sorghum.				
Kaira, Gandhinagar, Mehsana and Sabarkanta districts and parts of Ahmedabad, Pancha mahals, Banaskantha and Vadodara districts of Gujarat in hot dry semi-arid entisols / inceptisols	Pearlmillet Sorghum Fingermillet Pigeonpea Castor	Clusterbeans Castor Fodder sorghum	Operations like thinning of plants to be carried out. If rainfall received during this period the sowing of castor and fodder sorghum may be carried out.	Castor Fodder sorghum Fodder sorghum + Karingada	Tobacco	Tobacco	—
Jhansi, Banda, Hamirpur, Lalitpur, Dhirpuri, Merona, Gwalior Morena in hot moist semi-arid inceptisols	Sorghum Pigeonpea Soybean Groundnut	Pearlmillet (grain and fodder) Clusterbean (grain and fodder) Cowpea (grain and fodder) Pigeonpea (grain) Blackgram (grain) Greengram (grain) Sesame (grain) Sorghum (fodder) Maize (fodder)	Pearlmillet (grain and fodder) Clusterbean (grain and fodder) Cowpea (grain and fodder) Pigeonpea (grain) Blackgram (grain) Greengram (grain) Sesame (grain) Sorghum (fodder) Maize (fodder)	Pearlmillet (grain and fodder) Clusterbean (grain and fodder) Cowpea (fodder) Pigeonpea (grain) Blackgram (grain) Greengram (grain) Sesame (fodder) Sorghum (fodder) Maize (fodder)	—	—	—

1	2	3	4	5	6	7	8
Hyderabad, Ranga Reddy and Nalgonda districts, parts of Medak, Karimnagar and Warangal districts of Andhra Pradesh in hot moist semi-arid alfisols	Sorghum Castor Pearlmillet Pigeonpea	Castor Pearlmillet (MBH – 1100) Bunch variety of Groundnut (TMV-2, JL-24) Pearlmillet + pigeonpea (2:1)	Setaria (H-1, Arjuna) Castor (Aruna, GAUCH –1) with increased seed rate (15 kg/ha)	Castor cv. Kranthi Pearlmillet	Cowpea Horsegram Setaria	Horsegram	—
Parts of districts of Jammu and Kithus of Jammu and Kashmir in sub-montane warm sub-humid inceptisols	Maize Sorghum Pearlmillet Greengram Blackgram Cowpea Sesame Castor	Pearlmillet Cowpea Greengram (direct sown) Pearlmillet (transplanting)	Pearlmillet + cowpea / clusterbean (fodder) Sorghum + cowpea Clusterbean (fodder) Maize + cowpea / clusterbean (fodder)	Pearlmillet + Cowpea / clusterbean (fodder) Sorghum + cowpea Clusterbean (fodder) Maize + cowpea / clusterbean (fodder)	Toria Gobhi Sarson	Wheat, Barley, Rapeseed, Linseed, Pea, Mustard	Wheat (C 306)
Jammu, Punch, Riasi, Muzzafarbad Kashmir South, Udhampur, Kathua in warm moist to dry subhumid podzolic soils	Maize Sorghum Pearlmillet Greengram Blackgram Cowpea Sesame Castor	Pearlmillet Cowpea Greengram Pearlmillet (transplanting)	Pearlmillet + cowpea / clusterbean (fodder) Sorghum + cowpea / clusterbean (fodder) Maize + cowpea / clusterbean (fodder)	Cluserbean (fodder) Preparation for September sowing	Toria Gobhi sarson	Wheat Barley Rapseed Linseed Pea Mustard	Wheat (C 306)
Apparent							
3.1 Apparent drought in dry sub humid region with 1000-1500mm (rainy season)							
Sub montaneous districts of Punjab, Jammu and Kashmir, Himachal Pradesh and western Uttar Pradesh in sub-montane hot sub-humid inceptisols	Maize Pearlmillet Groundnut Soybean Blackgram	Short duration Maize Greengram Blackgram Fodder crops of pearlmillet clusterbean sorghum and maize	Greengram and blackgram (first week of August). Fodder crops of pearlmillet, clusterbean/ maize Green manuring of sunhemp incorporated for better yield of following *rabi* crops.	Fodder crop of pearlmillet In fallow land, ploughing and repeated planking may be done for soil moisture conservation to following *rabi* oilseeds and pulses	Linseed Pea Mustard	Wheat, Barley, Rapeseed, Linseed, Pea, Mustard	Wheat (C 306)

1	2	3	4	5	6	7	8
Raipur, Pilibhit, Bareily, Sitapur, Ghazipur districts and parts of Shajahanpur, Kheri, Lucknow, Barabanki, Rae Bareli, Saltanpur, Azamgarh, Mau in hot dry subhumid Vertic inceptisols	Maize	Short duration upland rice (NDR-97, NDR-118, Barani deep, Cauvery, Akashi, Mutmuri) is recommended. In sandy loam and sandy soils sowing of green gram (T-44, Pant Moong-2), blackgram (T-9, Pant Urd-19, Pant Urd-35 and Narendra Urd-1), Pigeonpea (Bahar and Narendra Arhar-1) Sesamum (T-4, T-12 and T-13)	Pearlmillet (NHB-3, NHB-4 and BJ-104) Greengram Black gram/ pigeonpea Sesame (Ootacamund) Niger (GA-10), Short duration upland rice varieties	Greengram in second fortnight of August. Pigeonpea (Bahar) may be sown up to September with high seed rate (25 kg/ha) and narrow spacing (30 cm) With the above recommendation Niger (GA-10), Sesame (Ootacamund) can be sown Pearlmillet (BJ-104) Blackgram + pigeon pea Rice crop if already sown is not likely to succeed may be ploughed under to conserve the moisture in the soil. This may permit growing of *rabi* crops.	Chickpea Mustard Linseed	Chickpea Mustard Linseed	Barley Wheat
Indore, Ratlam, Ujjain, Dewas, Dhar, Khandwa and parts of Sahore districts of Madhya Pradesh in hot moist semi arid vertisols	Sorghum Maize Cotton Groundnut Soybean Pigeonpea	Maize – (short duration varieties like Navjot, Sathi, etc.) Pigeonpea - ICPL 151, T-21, Kh-2, ICPL 87, ICPL 88039 etc. in deep soils) Sunflower (Morden, Surya, Manjira and any other hybrids) Sesame (Bhadeli, TKG-22, TKG 37) Cowpea (Pusa Komal and Pusa Baisakhi) Castor (Gauch and Varuna) Fodder crops – *Sorghum sudanensis*, Maize (African tall). Dinanath grass and Pearlmillet etc.	Sunflower (Morden, Surya, Manjira and other hybrids Sesame (Bhadeli, TKG-22, TKG 37 etc.). Cowpea (Pusa Komal and Pusa Baisakhi) Castor (Gauch and Varuna). Fodder crops – Sorghum *sudanensis,* Maize (*African tall*) Dinanath grass and Pearlmillet.	Safflower (JSF-1, JSF-7 (spineless), JSF-73, Sharda) Sunflower (Morden, Surya and Manjira) Sesame (Bhadeli, TKG-2, and RT-46 Rajgira – Co-1, Co-2) Castor (Gauch, Varuna) Fodder crops (Barley, Oats), Maize (*African tall),* Safflower and sunflower	Safflower	Chickpea	Wheat

1	2	3	4	5	6	7	8
Uplands and medium lands of Balasore, Cuttack, Puri and Ganjam districts of Orissa in hot moist sub-humid inceptisols	Pigeonpea Mesta Maize Groundnut Fingermillet Rice Sorghum Cowpea, Blackgram, Greengram	Upland Blackgram Setaria (Pant -30) Greengram (PDM54/ K 851) Sesame (Uma or local) Early Pigeonpea (UPAS 120/ICPL-87) Planting of short duration vegetables as radish (Pusa Chetki), okra, cowpea (SEB-2/ SEB 1) and clusterbeans.	Upland Sowing of niger, blackgram, sesame, greengram, Planting of vegetables as radish, beans, cowpea, Early Pigeonpea (ICPL-87/UPAS-120) Medium and shallow submerged lowland Direct line sowing of extra early rice (Heera, Vandana, Kalinga-III, Z HU 11-26, Rudra, Sankar and Jaldi-5).	Upland Horsegram Sesame Niger Cowpea	Medium land Making land preparation for sowing pre-*rabi* crops as Mustard/ greengram/ early pigeonpea, which can be sown in the month of September Pigeonpea (short duration), Horsegram	Medium and low land conditions: Direct sown rice, transplanted rice Horsegram	—
Entire plateau of Chotanagpur and Santhal paraganas, parts of Rhotas, Gaya, Jamuin in Monghyr district, Banke subdivision of Bhagalpur district, and Purulia and Bankura districts of West Bengal in hot dry sub-humid alfisols (Ranchi).	Mesta Pigeonpea Fingermillet Sorghum Maize Groundnut Soybean Rice, *Kharif* potato	Fingermillet (all varieties) but spacing to be reduced from 20 x 15 to 20x10 cm, Greengram (Sunaina), Transplanting of fingermillet	Greengram (Sunaina), Blackgram (T.9), Sasame (Kanke white (normal sowing time), Krishna), Sweet potato (Cross 4 and Local (normal sowing time)	Niger (N.5) horsegram (BR 10 Madhu) are the natural choice for seeding Transplanting of fingermillet.	Toria	Safflower Linseed	Wheat

1	2	3	4	5	6	7	8
Sidhi, Rewa, Satna, Sahodol and Panna districts, northeastern parts of Jabalpur and Damoh districts and southern parts of Tikamgarh and Chattarpur districts of Madhya Pradesh in hot dry sub-humid vertisols	Rice Greengram Bean Pigeonpea Groundnut Sesame	Low land – direct Re-sowing of seeded rice is needed if plant population is less than 50%	Low land – direct Re-sowing of seeded rice is needed if plant population is less than 50%	Soybean Sorghum	Minor millets	Wheat Linseed Chickpea Lentil	Wheat (C 306) Safflower Barley
Varanasi, Mirzapur, Janupur, Ghazipur and Bali districts of Uttar Pradesh in hot dry sub-humid inceptisols	Upland Rice Maize Pearlmillet Blackgram Greengram Sesame	Emerging seedlings / standing crops can be saved with life saving irrigation. In case of delay of monsoon, application ofadditional 10 kg N in standing crop Shortduration pulses and fodder	Pigeonpea Greengram Blackgram. Fodder and minor millets	Pulses, blackgram, greengram and pigeonpea have performed better in uplands and medium lands and recommended for combating drought Besides, plantation of leguminous shrubs and non-timber plants can be thought of fodder crops of pearlmillet	Only short duration crops like grain legumes (black and greengram), pearlmillet (BJ.104) give a fair performance, blackgram in inter rows of pigeonpea was found successful, Rice crop may not likely to succeed may be ploughed.	Chickpea Barley Wheat Lentil Mustard Linseed Safflower	Wheat (C306) Mustard

Annexure II

Land capability, rainfall and soil order based integrated nutrient management practices

Land Capability Class	Rainfall 250-500 mm Aridisols	Inceptisols
I	Pearlmillet 40:8:0 NPK Clusterbeans/ mothbean 0:13:0 NPK Horsegram/ blackgram/ cowpea/ pigeonpea 20:13:0 NPK	Pear millet 40:8:0 NPK Horsegram/ blackgram/ cowpea/ pigeonpea 20:13:0 NPK Agroforestry trees are not fertilized, however crop components are fertilized as per recommended doses.
II	Pastures are grown on native soil fertility.	Same as above
III	Pastures are grown on native soil fertility. Fertilizers are not recommended in silvicultural species. Horticultural species receive recommended fertilizer doses as per the age and the species	Same as above. Pastures are grown on native soil fertility.
IV - V	No fertilizer for agroforestry species except for horticulture trees depending on age and type of species. Pastures are grown on native soil fertility.	
VI - VII	Generally fertilizers are not recommended in silvipasture system	
VIII	Fertilizer doses are not recommended	

	Rainfall 500-750 mm Vertisols	Alfisols
1 - IV	Pearl millet 75:11:0 NPK Shallow to medium deep soils Pearlmillet 50:25:0 NPK Rabi sorghum 50:0:0 NPK (9-10 t/ha Leucaena loppings can substitute 25 kg N/ha Safflower 50:25:0 NPK Chickpea 15:25:0 NPK (placement at 10 cm depth near seed row) Fallow – rabi sorghum system (FYM or crop residue +leucaena loppings during fallow). 50%N through crop residue (sorghum/ leucaena) + 50% N through fertilizer for rabi sorghum. / leucaena and gliricidia during fallow. **Medium to deep soils** Greengram/ rabi sorghum 25:50:0 NPK Sequence cropping 30:0:0 NPK Hybrid pearlmillet 40:40:40 NPK	Pearlmillet 75:11:0 NPK or 50:13:20 NPK; **Shallow soils** Groundnut 20:40:40 NPK Castor 40:40:40 NPK Pigeonpea 20:40:20 NPK Pearlmillet 40:40:40 NPK Setaria 40:40:40 NPK (for all crops N in 2 splits)2

	Rabi sorghum 30:25:0 NPK Pulses 20:40:0 NPK (basal) Leucaena loppings @ 5 t /ha can be used. For chickpea 50 kg N/ ha and 5t compost **Vertic to vertisols** Maize 50:30:0 NPK Maize+pigeonpea 50: 30:0 NPK (50%N can be given through organics) Sorghum 50:30:0 NPK Greengram/ blackgram/ cowpea 15:30:0 NPK Wheat/ barley/ safflower/ mustard 30:15:0 NPK (Reduce N by half in case previous crop was a legume) Chickpea/ lentil 15:30:0 NPK **Medium to deep vertisols** Groundnut 12.5 :25:0 NPK (basal) Sorghum 90:30:0 NPK (N in 2 splits) Pearlmillet 80:40:0 NPK (N in 2 splits) Cotton (GAU-cot-10) 40:20:0 NPK (N in 2 splits) Cotton (V-797&CJ.73) 25:25:0 NPK Sesamum 25:25:0 NPK Castor 50:50:0 NPK Greengram 20:40:0 NPK Pigeonpea 20:40:0 NPK (all basal). FYM @ 6t/ha is also recommended. Among INM practices, application of 6:12:0 NPK + mulching with sunhemp in between rows + rhizobium and phosphorus solubulizing bacteria is recommended.	
V	No fertilizer for agroforestry species. For alley cropped millets and legumes doses as mentioned above. For bushes of aromatic and medicinal plants, standard doses are applied depending on the age, production capacity per bush and kind of species.	
VI	As above	Fertilizers are recommended based on kind and age of horticultural tree species. For other crops doses are as above.
VII	Generally fertilizers are not recommended in silvipasture system	Fertilizer doses are not recommended. But for horticultural crops doses are recommended as per age and type of species.
VIII	Fertilizer doses are not recommended	

	Rainfall 750-1000 mm	
	Alfisols	**Inceptisols/Vertisols**
I - IV	Sorghum 40:13:0 NPK deep soils; 18:17:0 NPK shallow soils Fingermillet 50:22:25 NPK Maize 75:22:25 NPK	Sorghum 40:13:0 deep soils; 18:17:0 NPK shallow soils Fingermillet 50:22:25 NPK Maize75:22:25 NPK
	Medium deep soils	**Sub-montane region**
	Sorghum 40:30:0 NPK Castor 50:30:0 NPK Pigeonpea 10:30:0 NPK Fingermillet 40:30:0 NPK Pearlmillet 40:30:0 NPK	Maize and wheat (sandy loam-clay loam) 80:40:20 NPK (drill fertilizers at or before seeding) Maize and wheat (loamy sand- sand) 40:20:10 NPK (N in 2 splits to maize)
	Deep soils	Deep vertisols
	Fingermillet 50:50:25 NPK (N in 3 equal splits). Or combination of organic (FYM 10t/ha) and inorganic (50:40:25 NPK). Maize 75:50:25 NPK (N in 2 splits) Groudnut 25:50:25 NPK (N basal) Pigeonpea/ cowpea/ horsegram 25:50:25 NPK (N basal).	Soybean –wheat: In case of soybean FYM@ 6t/ha+ 20:30:0 NPK. Substitute 50% of fertilizer N through FYM
	Bundelkhand region	
	Clusterbean 15:60:0 NPK and inoculation with rhizobium is recommended. In order to improve the yields of rabi crops, in-situ incorporation of sunhemp at 45 days prior to rabi crops to improve the yield.	
V	Same as above	For horticulture trees, doses as per age and type of species. Others as above.
VI	For bushes of aromatic and medicinal plants, standard doses are applied depending on the age, production capacity per bush and kind of species.	For millets and legumes as mentioned above. No fertilizer for agroforestry tree species. For horticulture trees (doses as per age and type of species)
VII	For horticultural crops, fertilizer doses are recommended as per age and type of species.	
VIII	Fertilizer doses are not recommended	
	Rainfall 1000 –1250 mm and more	
	Inceptisols/Entisols/Vertisols	**Oxisols**
I	Maize 40:9:10 NPK Upland rice 40:18:0 NPK Pulses, Chick pea 10:11:0 NPK Oilseeds 10:11:0 NPK	**Chota Nagpur plateau region** Application of 30:20:0 NPK in upland rice (local). Hybrid rice 60:30:0 NPK
	Sub montane region	For medium land the doses can be
	Pearlmillet 50:30:15 NPK (in 2 splits) Maize 75:40:30 NPK (placement 5cm below/ away from seed) Wheat 50:30:20 NPK (placement 10 cm deep) Barley 40:20:10 NPK (placement 10 cm deep)	increased. 75-90:60:40 NPK (apply N in 3 splits) Wheat 30:20:0 NPK (apply N in 3 splits) Barley 30:20:20 NPK (all basal).

	Cowpea 15:45:0 NPK Greengram/ blackgram 15:45:0 NPK Sarson 40:60:20 NPK (N in 2 splits) For maize + blackgram (mash) intercropping system, conjuctive use of organics (40 N) and inorganics (50 N) **Alluvial soils** Upland rice and Barley, 80 N, Wheat 60 N Chickpea 40 P Sesamum/ mustard/ safflower 40 N Linseed 40:20:0 NPK (in 2 split doses in kharif, while as basal in rabi). **Baghelkhand plateau (Vertisol)** In case of chickpea use of biofertilizers such as Rhizobium + phosphate solubilising bacteria (PSB) is recommended **Eastern Maharastra plateau (Vertisol)** 5 t of FYM + 40 P + microbial culture @1.5 kg/ha is recommended for pigeonpea.	Safflower 20 N (N in 3-4 splits), Chickpea 0:20:0 NPK
II	Same as above	Application of 30:20:0 NPK in upland rice For medium land the doses can be increased. 75-90:60:40 NPK (apply N in 3 splits)
III	Same as above. Doses as per age and type of species for horticulture trees.	Same as above
IV	Same as above. Doses as per age and type of species for horticulture trees.	Same as above
V	Doses as per age and type of species for horticulture trees	Same as above
VI	Doses as per age and type of species for horticulture trees	
VII	Fertilizer doses are not recommended in general. But doses are recommended as per age and type of species for horticultural crops	Fertilizer doses are not recommended.
VIII	Fertilizer doses are not recommended	

Note : P is P_2O_5; K is K_2O; NPK kg/ha

Annexure III

Refinements for some indigenous water harvesting systems

Indigenous	Area system	Description	Merits	Refinements proposed
Khadin	Aridisols of Jaisalmer districtm, western Rajasthan	A check dam is constructed across the plain valley when an ephemeral stream carrying runoff from the rocky catchments to valley area. The bund is provided with waster weir/ spill way.	• Main source of irrigation • Erosion control • Water table recharge	• Treatment of upper reaches • Lining for maintenance
Nadi (village pond)	Inceptisols of Bhilwara district, Rajasthan	Digging and filling the soil in a phase manner. Digging one basement at the mouth of the nala	• Practiced in areas with saline ground water • Runoff collection for life saving irrigation • Ground water quality improvement	• Land treatment with low cost measures • Lining of pond • Efficient use of harvested water • Dimension of the pond
Sand bags as gully checks	Alfisols of Anantapur, Andhra Pradesh	Gully control and runoff management by stacking of sand filled bags, constructed in off season	• Alternative to masonry check dam	• Design of the structure • Bags made of thick poly sheets for increasing life of structure
Percolation tanks	Alfisols of Andhra Pradesh and Karnataka	Impounding surface runoff in tanks constructed across the nalas	• Ground water recharge • Reduction in sediment loss	• Permanent measures to check to breaching of the tank bund • Approporiate location as per geo-hydrological condition
Conservation ditches	Vertisols of Vidarbha	Inverted contour bunds in deep black soils of Vidarbha in between farmers' fields. Maintained in alternate years	• Runoff collection • Erosion control • Drinking for livestock	• Proper designing of ditches • Community involvement for wider adoption
Waste weirs	Vertisols of Bijapur Karnataka and Solapur, Maharashtra	Crest length: 2-15 m Height: 0.3 – 3 m	• Safe disposal of surplus water • Water storage • Reduction in sediment loss	• Treatment for avoiding frequent maintenance (Vegetal/ permanent) • Design of suitable waste weirs

Annexure IV

Prioritized rainfall based soil and water conservation measures

Land Capa-bility Class	Rainfall <500 mm	Rainfall 500-750 mm	Rainfall 750-1000 mm	Rainfall >1000 mm
I	**Conservation furrows** **Mulching** **Ridging** **Sowing across slope** **Tied ridges** **Tillage** *BBF* *Inter row system* *Small basins* Contour bunds Field bunds Khadin	**Conservation furrows** **Mulching** **Ridging** **Sowing across slope** **Tied ridges** **Tillage** *BBF* *Inter row system* *Small basins* Contour bunds Field bunds Khadin	**Conservation furrows** **Mulching** **Sowing across slope** **Tied ridges** **Tillage** *BBF* *Graded fidging(High RF)* *Lock and spill drains* *Small basins* Field bunds Graded bunds Nadi	**Conservation furrows** **Sowing across slope** Field bunds Graded bunds Choes Level terraces *BBF* *Graded ridging (High RF)*
II	**Conservation furrows** **Contour farming** **Mulching** **Ridging** **Sowing across slope** **Tied ridges** **Tillage** *BBF* *Contour strip forming* *Inter row system* *Small basins* Contour bunds Field Bunds Khadin Inter plot water harvesting	**Conservation furrows** **Contour farming** **Mulching** **Ridging** **Sowing across slope** **Tied ridges** **Tillage** *BBF* *Contour furrows/ Strip tillages* *Lock and spill drains* *Runoff Strips* *Small basins* Contour bunds Field Bunds Khadin Zingg terrace	**BBF** **Conservation furrows** **Contour farming** **Mulching** **Sowing across slope** **Tied ridges** **Tillage** *Graded ridging-(High RF)* *Lock and spill drains* Field bunds Graded bunds Nadi Zingg terrace	Field bunds Graded bunds Bundhi Zingg terrace Level terraces *Contour strip forming* *Graded ridging-(High RF)* *Lock and spill drains* Contour farming Sowing across slope Tillage

III	**Contour farming** **Mulching** **Ridging** **Sowing across slope** **Tied ridges** **Tillage** *BBF* *Strip tillages* *Contour strip farming* *Lock and spill drains* *Runoff strips* *Small basins* Contour bunds Field bunds Khadin Inter plot water harvesting Zingg terrace	**Contour farming** **Mulching** **Ridging** **Sowing across slope** **Tied ridges** **Tillage** *Contour furrows/* *Contour furrows/* *Contour strip forming* *Lock and spill drains* *Runoff strips* Contour bunds Field bunds Nadi Zingg terrace	**Contour farming** **Sowing across slope** **Tillage** *Contour strip forming* *Graded ridging-* *(High RF)* *Lock and spill drains* *Strip tillages* Field bunds Graded bunds Zingg terrace Bundhi	**Contour farming** **Sowing across slope** **Tillage** *Small pits* *Contour* *strip forming* *Lock and spill drains* Field bunds Graded bunds Level terraces Live hedges Bundhi
IV	**Contour farming** **Ridging** **Sowing across slope** **Tied ridges** **Tillage** *Contour furrows/* *Strip tillages* *Contour strip forming* *Lock and spill drains* *Runoff strips* *Small basins* *Small pits* Field bunds Zingg terrace	**Contour farming** **Sowing across slope** **Tillage** *Contour furrows/* *Strip tillages* *Contour strip farming* *Graded ridging-* *(High RF)* *Lock and spill drains* *Runoff strips* *Small pits* Field bunds Live hedges Zingg terrace	**Contour farming** **Sowing across slope** **Tillage** *Contour furrows/* *Strip tillages* *Contour strip farming* *Lock and spill drains* *Small pits* Field bunds Live hedges	**Contour farming** **Sowing across slope** **Tillage** *Contour strip farming* *Lock and spill drains* Field bunds Graded bunds Live hedges Trapezoidal catchments
V	*Outward Terraces* *Semi circular basins* *Small pits* Hillside ditches Live hedges Semi circular Catchments Staggered trenches	*Outward terraces* *Semi circular basins* *Small pits* Hillside ditches Live hedges Semi circular Catchments Staggered trenches Trapezoidal catchments	*Outward terraces* *Semi circular basins* *Small pits* C.contour trenches Hillside ditches Live hedges Semi circular Catchments	C.contour trenches California type with Vegetative barrier Graded terraces Hillside ditches Trapezoidal catchments Vegetative buffer strips

	Land levelling coupled with surface drainage for black soils Check basins for saline soils	Surfaced rainage for black soils Check basins for saline soils	Surface drainage/ vertical drainage for black soils Subsurface drainage for saline soils	Subsurface drainage for saline soils
VI	*Outward terraces* *Semi circular basins* *Small pits* Hillside ditches Live hedges Semi circular catchments Staggered trenches	*Outward terraces* *Semi circular basins* *Small pits* Hillside ditches Live hedges Semi circular Catchments staggered trenches	C.contour trenches Hillside ditches Inward terraces Semi circular Catchments Trapezoidal catchments Vegetative buffer strips	California type with vegetative barrier Graded terraces Trapezoidal catchments Vegetative buffer strips *Graded trenches* *Vegetative barrier*
VII	*Outward terraces* *Semi circular basins* *Small pits* Hillside ditches Semi circular Catchments Staggered trenches Vegetative buffer strips	Hillside ditches Inward terraces Semi circular catchments Staggered trenches Trapezoidal catchments Vegetative buffer strips	C.contour trenches California type with Mechanical barrier Graded terraces Trapezoidal catchments Vegetative buffer strips	California type with mechanical barrier Graded terraces Vegetative buffer strips *Graded trenches*
VIII	Hillside ditches Inward terraces Staggered trenches Trapezoidal catchments Vegetative buffer strips	C.contour trenches California type with mechanical barrier Hillside ditches Inward terraces Trapezoidal catchments Vegetative buffer strips	Graded trenches Graded terraces mechanical barrier California type with Trapezoidal catchments	California type with mechanical barrier Graded terraces *Graded trenches*

Bold	**Farmer oriented Temporary/recurring measures**
Italics	*Farmer oriented Semi permanent measures*
Normal	Community oriented permanent measures
BBF	Broad bed-furrow
RF	Rainfall
C	Continuous

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