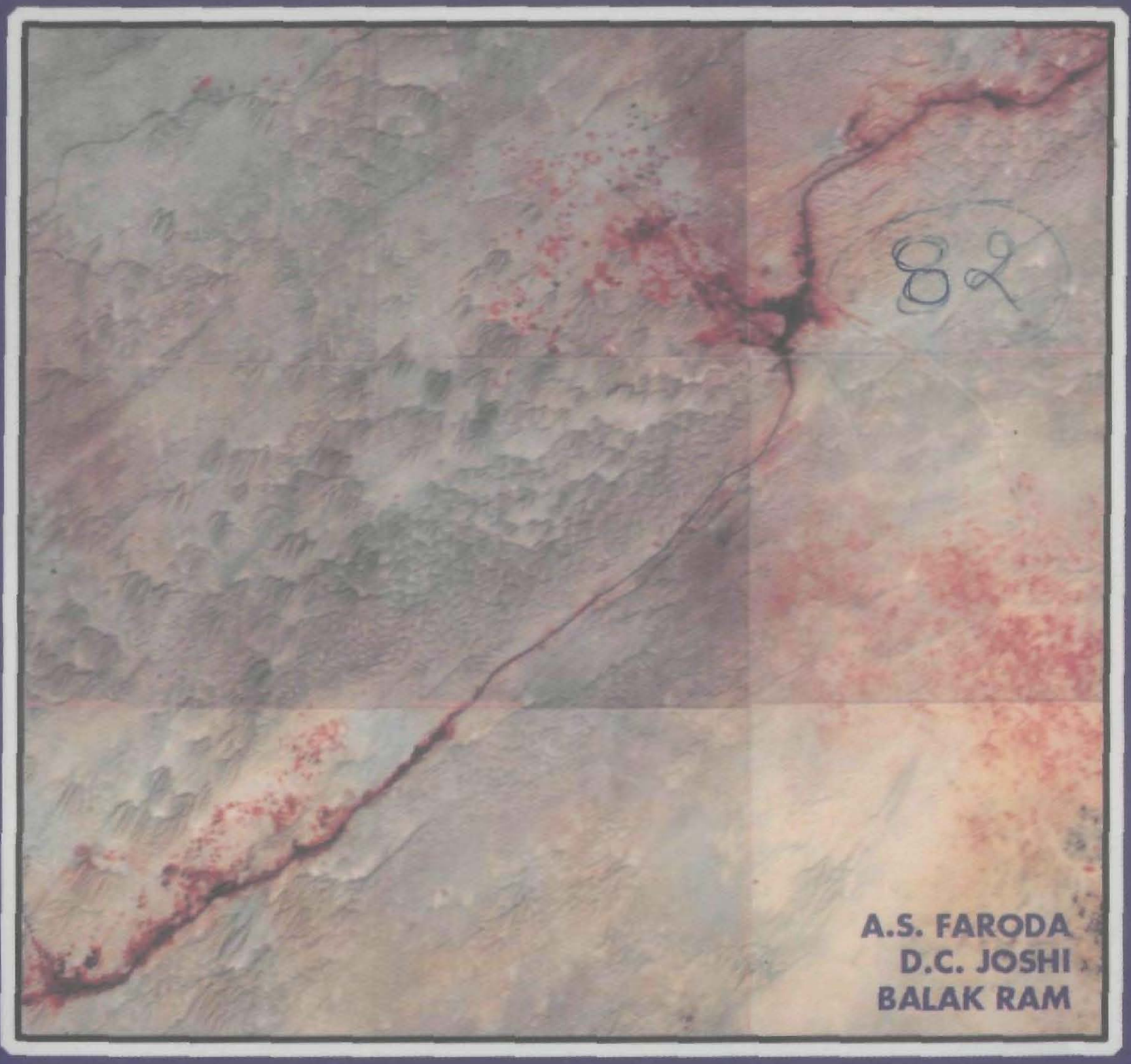
AGRO-ECOLOGICAL ZONES OF NORTH-WESTERN HOT ARID REGION OF INDIA



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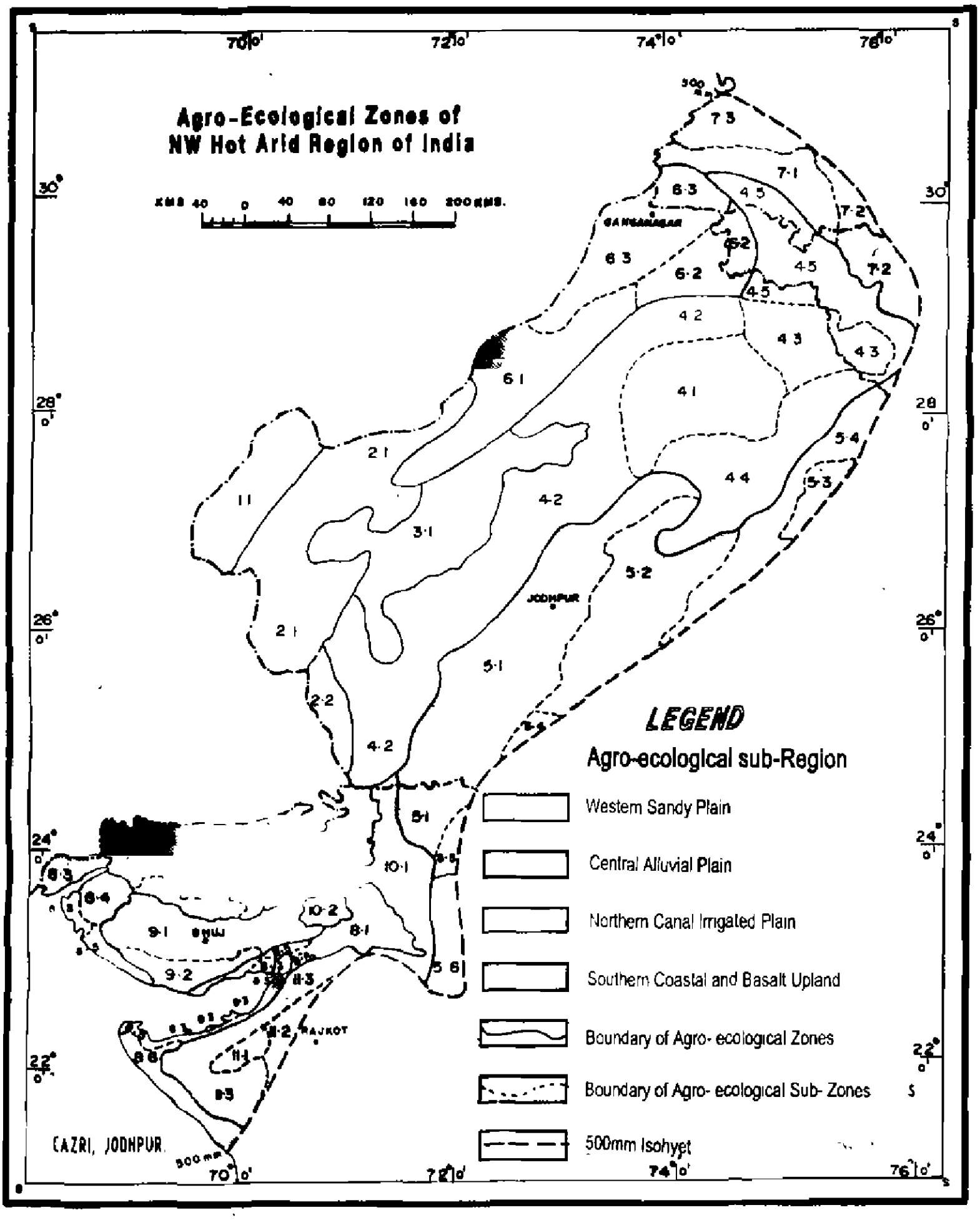

Agro-Ecological Zones of North Western Hot Arid Region of India

Identification of homogeneous agro-ecological zones is necessary for sustainable *utilization of land, water and other natural resources for development through* transfer of suitable technology. Development planning based on characteristics of agro-ecological zones is much relevant to achieve higher production. The stretegy is more relevant in arid region of India, which is characterized by inhospitable climate, scarce resources and increasing biotic pressure due to human and animal population.

In past few decades several attempts have been made at national and regional levels to recognize agro-climatic and agro-ecological zones in the country. Krishnan (1968) delineated the boundaries of arid and semiarid zone of the country. The Planning Commission, Government of India, recognized 15 agro-climatic regions for the entire country which were uniform with respect to land and water endowment, out of which three occur in north western hot arid region of India (Basu and Guha, 1996). National Commission on Agriculture in the year 1974, based on the quantum of rainfall received during the rainy season, subdivided the arid region of Rajasthan in three zones. The Indian Council of Agricultural Research (ICAR), under the auspices of the National Agricultural Research Projects (NARP) have identified 126 agro-climatic zones in the country, out of which 10 occur in north-western arid region (Ghosh, 1991). The National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) based on physiography, soil and length of growing season identified 54 agro ecological zones (Sehgal *et al.*, 1989). Subsequently the Bureau published another map with 21 agro-ecological regions (Sehgal *et al.*, 1990).

The northwestern arid region of India has large spatial variability in climate and land resources. The agro-climatic/agro-ecological zones recognized by different agencies/organizations have large variations in rainfall, terrain/soil characteristics and surface and ground water potentials, which have different technological requirement. There is need to classify the entire northwestern hot arid region into homogeneous agro-ecological zones/sub zones so that a uniform package for development can be adopted.

Environmental Setting

The arid region of India is spread in 38.7 million hectare (m ha) area out of which 31.7 m ha is under hot arid zone and 7 m ha under cold arid zone. The hot arid region occupies major part of northwestern India (28.57 m ha) and occurs in small pockets (3.13 m ha) in south India. The northwestern arid region occurs between 22^0 30", to 32^0 05"N and from 68^0 05" to 75^0 45"E covering western part of Rajasthan (19.6 m ha, 69%), Gujarat (6.22 m ha, 21%) and south-western parts of Haryana and Punjab (2.75 m ha, 10%). The region is bordered by the irrigated Indus plain in the north, Aravalli hill range in the east, international border with the Pakistan in west and black soil region and alluvial plain of Sabarmati in the south.

The northwestern arid region receives low rainfall (<100 mm to over 400 mm), has high evapo-transpiration and high temperature regime. Ground water is deep and often brackish. The ephemeral rivers flow at the northern, eastern and southern fringes of the region. Western and central area is devoid of integrated drainage system and surface water resources are meagre. Soils in this region are coarse textured, covered with sand dunes. Low available water capacity, vulnerability to wind erosion and low fertility are major constraints. High salinity, calcareousness and gypsiferous nature are another dimensions added to these soils. Rainfed agriculture combined with animal husbandry is the major basis of livelihood of desert dwellers. Frequent droughts result in failure of crops, at times, migration of animal and human population.

Methodology

During Integrated Resources Survey of arid region, over last four decades valuable information has been generated on the physiography, distribution and characterisistcs of soils, surface and ground water resources, natural vegetation and land use by the CAZRI. Agroclimatic/Agro-ecological zones proposed by Planning Commission, National Agricultural Research Projects (NARP) and National Bureau of Soil Survey and Landuse Planning have also been considered. After correlation and collation of these information the northwestern hot arid region has been classified according to following criteria.

Agro-ecological sub regions : Physiography, rainfall and water resource (surface water through streams, canals and ground water).

Agro-ecological zones : Landform-soil association and landuse.

Agro-ecological sub zones : Integrated approach involving terrain characteristics, parent material; soil texture, depth and salinity; surface and ground water potential and cropping pattern.

The sub zones are uniform with respect to potentials and constraints limiting rainfed and/or irrigated agriculture and silvipasture and will require specific technology for sustained development.

Based on above criteria, entire northwestern hot arid region has been classified in four agro-ecological sub regions, eleven zones and thirty-four sub zones. Their distribution and extent have been mapped (Fig. 1) and summarized in Table-1. The spread of sub zones up to districts and tehsils/taluka has been given in Table-2. Salient characteristics of sub-regions, agro-ecological zones and sub zones and technological requirements for sustainable development of each of the sub zones have been given below.

WESTERN SANDY PLAIN SUBREGION (1.27 m ha 44.5%)

This sub region is most extensive and occurs in the western and northern parts of the arid region. It has been classified in four zones and nine-sub zones. The region has been characterized by dune complex physiography, less than 200-mm rainfall and poor surface and ground water resources.

1. Hyper arid zone (0.86 m ha 3 %)

The zone is characterized by Torripsamments soils associated with dune, sandy waste and absence of arable cropping is the land use. The zone has one sub zone.

1.1 Hyper arid (0.86 m ha 3%) : This sub zone occurs in western part of Jaisalmer district and characterized by highly dune complex terrain, Torripsamments (D) soils, less than 100 mm rainfall, high wind speed and intense solar radiation during summer, sandy waste landuse. Due to difficult dune terrain major part of the sub zone is not approachable. Scarce water resources, severe wind erosion and difficult terrain are major constraints. Technologies for harnessing wind power and solar energy are needed. The area has strategic importance.

2. Dune complex with scrub and grasses (2.32 m ha 8.1%)

The zone is characterized by sand dunes, Torripsamments soils, open grazing landuse and occasional rainfed cultivation and has been classified in two sub zones.

2.1 Western dune complex with Lasiurus sindicus (2.06 m ha 7.2%) : Vast stretches of sand dunes, Torripsamments (D) soil, receiving 100 to 150 mm rainfall, covered with *Lasiurus sindicus (sewan)* grass has been classified in this sub zone. The sub zone occurs in Jaisalmer, Barmer and Bikaner districts. Low rainfall, scarce water recources, uneven sandy surface and wind erosion are the major constraints. Protection of these grasslands from biotic interference is required.

2.2 Western dune complex with scrub (0.26 m ha 0.9%) : The sub zone characterized by dune complex terrain, Torripsamments (D) soils with 100 to 150 mm mean annual rainfall, and scrub vegetation cover occurs in Barmer district. Severe wind erosion, scarce water resources and over grazing are major constraints. Technologies are required for sand dune stablization, livestock based farming, creation of water bodies for animal drinking and agro-silvi-pasture system and khadin cultivation.

3. Hard pan zone (1.57 m ha 5.5%)

The zone is characterized by sandy plain having hard and compact substrata at shallow depth, which is impervious to roots and water. Limited rainfed *Kharif* cultivation with vast open grazing is the land uses. The zone has one sub zone.

3.1 Hard pan soil (1.57 m ha 5.5%) : This sub zone extends in the Jaisalmer, Barmer and Jodhpur districts and characterized by thin cover of sandy soils underlain by compact lime concretionary/gravelly pan classified as Petrocalcids, Lithic Cambids, Lithic Calcids. Mean annual rainfall varies between 150 to 250 mm. Open grazing with limited cultivation is the major landuse. Constraints associated with the sub zone are shallow soil depth, low available water capacity and scanty water resources. Technologies are needed for establishment of pastures, silvipasture and agroforestry involving shrubs and runoff water harvesting.

4. Sandy plain with scattered dunes (7.96 m ha 27.9%)

Plain with sandy hummocks and scattered dunes, associated with Torripsamments (P) sandy, deep to very deep and calcareous soils in 250 to 450 mm rainfall, forms biggest zone. Rainfed agriculture with pearl millet based cropping is the major landuse. Moth bean, moongbean and guar are essential legume components. Limited area is irrigated with ground water, which is saline/sodic at places. Grazing lands are in highly degraded condition. Productivity of the zone is low because of erratic rainfall, coarse textured soils and poor quality of ground water. The zone has been classified in five sub zones.

4.1 Eastern dune complex with limited cultivation (1.32 m ha 4.6%) : The sub zone covered with sand dunes/interdunes and Torripsamments (D) soils with scarce surface and ground water resources is under rainfed agriculture with 250 to 350 mm rainfall in Bikaner, Churu, Sikar and Jhunjhunu districts. Uneven surface, loose sandy soils with low available water capacity and fertility,

vulnerability to wind erosion and meagre water resources are major constraints. Technologies needed are stabilization of mobile sand dunes, wind break and shelterbelt plantation, drought tolerant varieties and *insitu* water harvesting.

4.2 Sandy plain with less than 300 mm rainfall (3.68 m ha 12.9%) : The Torripsamments (P), Haplocambids and Haplocalcids soils in 250 to 300 mm rainfall zone, with deep and brackish ground water are mainly under rainfed cropping. The sub zone extends in Jalor, Barmer, Jodhpur, Nagaur, Bikaner, Churu and Ganganagar districts. Frequent droughts, low available water capacity and fertility of sandy soils are the major constraints. Technologies involving livestock based farming with *insitu* water harvesting, agro-forestry is needed for this sub zone.

4.3 Sandy plain with more than 300 mm rainfall (0.70 m ha 2.4%) : This sub zone includes the Torripsamments (P and D) soils having limited irrigation with brackish ground water in 300 to 450 mm rainfall zone (part of which is also received in winter). The sub zone occurs in Ganganagar, Churu, Jhunjhunu and Bhiwani districts. The sub zone is mainly under rainfed cropping in *kharif* and *rabi*. Technologies involving dryland practices and agro-foresty/agro-horticulture are needed for this sub zone.

4.4 Sandy plain with inland drainage (1.25 m ha 4.4%) : The sub zone characterized by Torripsamments (P) and Haplocambids in 300 to 400 mm rainfall zone have poor surface and ground water resources and occurs in Nagaur, Sikar, Churu and Jhunjhunu districts. It is under rainfed agriculture with limited irrigation in *rabi* in pockets. Technologies involving dryland practices, watershed approach, agro-forestry/agro-horticulture and management of brackish water for irrigation are needed for this sub zone.

4.5 Western Haryana and Punjab plain (1.01 m ha 3.6%) : The Ustipsamments (P and D), Torripsamments (P and D) and Haplocambids soils in 350 to 450 mm rainfall zone with rainfed and irrigated rabi cropping in this sub zone occur in

Hisar, Sirsa, Bhiwani and Bhatinda districts. This is a productive sub zone and requires technologies involving improved seeds, integrated nutrient and pest management and *in situ* moisture conservation.

CENTRAL ALLUVIAL PLAIN SUB REGION (5.45 m ha 19%)

The alluvial plain has been formed of the sediments deposited by rivers, the Luni and the Banas. Eastern boundary of the sub region coincides with Aravalli hill range and western boundary merges with the sandy plain. Rainfall ranges from 350 to 450 mm. A number of streams originating from Aravalli hill ranges flow through the area and contribute to surface and ground water resources. The zone offers good sites for watershed management. The sub region has one zone.

5. Luni-Banas basin (5.45 m ha 19%)

The zone is an alluvial plain characterized by Haplocambids, Haplocalcids and Haplosalids under rainfed *kharif* and irrigated *rabi* cropping including cash crops like cumin, condiments and cotton. The zone has been classified into six sub zones.

5.1 Luni basin with coarse loamy soils (2.67 m ha 9.4%) : The sub zone characterized by alluvial plain of Haplocambids and Haplocalcids soils with brackish ground water extends in Jalor, Barmer, Pali, Nagaur and Jodhpur districts. The loamy sand and sandy loam soils have better available water capacity but for *rabi* crops scarce water resources, brackish ground water for irrigation, salinity in soils are the constraints. Technologies are needed for management of brackish water irrigation and salt tolerant varieties for *rabi* crops. For *kharif* high yielding varieties and improved *in situ* moisture conservation for bajra-moong-til based cropping and agro-horticulture loamy sand and sandy loam soils are required.

5.2 Luni basin with fine loamy soils (1.44 m ha 5.0%) : The alluvial plain in the rainfall zone of 300 to 450 mm has Haplocambids, Haplocalcids and Haplosalids.

The soils are fine textured with good surface water runoff, brackish ground water and limited irrigation through canal. The sub zone is spread, in Pali, Jalor, Jodhpur and Nagaur districts. Rainfed *kharif* and under conserved moisture *rabi* crops, brackish water irrigated *rabi* and silvipasture on salt affected soils are the land uses. This is a very productive zone and technologies for *in situ* moisture conservation, improved seeds and agronomic practices for cash crops like cumin, *isabgol*, coriander, *sonf*, mustard and cotton will further increase the crop yields.

5.3 Mendha basin (0.17 m ha 0.6%) : The sub zone spread in Sikar and Nagaur districts receives 400 to 450 mm rainfall and is associated with Haplocambids, Torrifluvents, Torripsamments (P) and Haplosalids soils with lot of alluvial activity. Because of coarse to medium textured soils and good quality water for irrigation the sub zone has intensive irrigated cropping of wheat, mustard, cotton and spices in *rabi* and rainfed cropping in *kharif*. Water and wind erosion is major constraints. Technologies for control of gullies and wind erosion and intensive cropping in irrigated areas are needed for higher yields.

5.4 Aravalli foot hill (0.76 m ha 2.6%) : The sub zone is characterized by shallow skeletal soils interspersed with rocky outcrops and fine textured deep soils classified as Haplocambids and Lithic Cambids, abundant surface and poor ground water resources occurs in Jhunjhunu, Sikar, Nagaur, Pali, and Jalor districts. Maize, sorghum, sesamum, pearl millet are major rainfed crops associated with orchards. Severe water erosion due to gullies and rills, high overland flow and shallow gravelly areas are major constraints. Technologies are needed to conserve and carry the runoff water, to develop orchards and intensification of crop production in small basin areas.

5.5 Aeo-alluvial plain of Banas (0.07 m ha 0.2%) : The alluvial sandy, deep soils classified as Ustipsamments with good surface and ground water and 450 to 500 mm rainfall occur in Banaskantha district. The alluvial plain is very productive and all the irrigated and rainfed cash crops including condiments and orchards are

cultivated in this sub zone. Sandy nature of soil vulnerable to wind erosion, high infiltration and percolation and low fertility are major constraint. Technologies for increasing the yields of spices, oil seeds and pulses, shelter belt and wind break plantations, agro-horticulture and orchard development with judicious water management are required.

5.6 Sabarmati plain (0.34 m ha 1.2%) : The sub zone consists of sandy loam deep soils classified as Haplocambids and Ustipsamments (P) with good ground and surface water resources occur in Banaskantha, Mehsana and Surendranagar districts. The alluvial plain is very productive and all the irrigated and rainfed cash crops including condiments, orchards are grown. The region has constraints due to low soil fertility and occasional brackish ground water. Technologies are needed to increase the yields of agro-horticulture crops by following integrated management.

NORTHERN CANAL IRRIGATED SUB REGION (4.21 m ha 14.7%)

The sediments deposited by the river Indus and its tributaries and reworked by the subsequent aeolian activities have formed the alluvial plain. The sub region has extensive irrigated area through canal net work of Gang, Bhakra and IGNP systems. The area occurs in the Ganganagar, Hanumangarh and Bikaner districts of Rajasthan and southern part of Haryana and Punjab. The sub region has been classified in two zones and six sub zones.

6. Canal irrigated sandy plain (2.78 m ha 9.7%)

The zone extends in the western and eastern part of the sub region irrigated by IGNP canal. The soils are coarse sandy associated with sand dunes and veneer of sand. Irrigated intensive cropping of cotton, mustard, wheat and Groundnut is the major landuse. The zone has been divided in three sub zones.

6.1 Dune complex with canal irrigation (1.18 m ha 4.1%) : The sub zone occurs in Jaisalmer and Bikaner districts with 150 to 250 mm rainfall. It is covered by high sand dunes associated with interdunes having Torripsamments (P), Petrocalcids and Petrogypsid soils. These areas have constraints due to uneven topography, severe wind erosion, petrogypsic and petrocalcic horizons, high infiltration, waterlogging and salinisation. Technologies are needed for sand dune stabilization, silvipasture on sand dunes and judicious irrigation in interdunes and management of waterlogged and salinised areas.

6.2 Aeolian plain of north east (0.55 m ha 1.9%) : This sub zone, a vast aeolian sandy plain covered with occasional low sand dunes called Tibbis, Torripsamments (P) and Haplogypsids soils and 250 to 300 mm rainfall occurs in Ganganagar, Hanumangarh, Sirsa and Faridkot districts. Sandy soils of fine and very fine grade sand fractions, low fertility, gypsic horizon, water table rise, water logging and salinisation are the major constraints in this subzone. Integrated nutrient management, judicious irrigation for high yielding varieties particularly for cotton and paddy and improved technolgies for citrus orchards are required.

6.3 Ghaggar flod plain (1.06 m ha 3.7%) : The sub zone is an alluvial plain characterized by Torrifluvents (P), Torripsamments (P) and Haplosalids soils with 250 to 300 mm rainfall. The sub zone extends in Ganganagar, Hanumangarh, Firozpur and Faridkot districts. This sub zone forms the most productive belt of cotton, paddy and sugarcane but at places water logged and saline soils are encountered. Technologies for integrated nutrient and pest management, judicious use of canal water for irrigation and management of waterlogged and saline soils are required for sustainable management of the sub zone.

7. Canal irrigated alluvial plain (1.43 m ha 5.0%)

The zone occurs in the northern and central part of sub region. It covers the alluvial plain of the rivers Sutlej and Yamuna spread in the arid region of Punjab and Haryana. The soils are very fine sand to loam and clay loam. Availability of

irrigation through the network of canals and medium textured soils have boosted the productivity of cotton, paddy, sugarcane and mustard crops in irigated areas. The zone has been classified in three sub zones.

*7.1 **Sutlej plain with coarse loamy soils*** (0.54 m ha 1.9%) : The sub zone characterized by Ustipsamments (P) soils and 400 to 500 mm rainfall occurs in southern part of Firozpur, Faridkot, Bhatinda and Hisar districts. Rainfed *Kharif* cropping include pearl millet, moongbean and guar. Under irrigation wheat and paddy are major crops. Water logging, salinisation and nutrient deficiency are the major constraints. Efficient methods of irrigation, agro-horticulture and intergrated nutrient management are required to sustain productivity of this sub zone.

*7.2 **Yamuna plain with loamy soils*** (5.1 m ha 1.8%) : The alluvial plain characterized by Haplocambids, Ustochrepts and Ustorthents soils with 450 to 500 mm rainfall occurs in Sangrur, Hisar, Jind and Bhiwani districts. Sugarcane, paddy, wheat, gram, maize and sorghum are the major crops. The sub zone is very responsive to high technologies including integrated nutrient and pest management, irrigation water management and improved varieties.

*7.3 **Sutlej plain with fine loamy soils*** (0.37 m ha 1.3%) : The Sutlej plain is characterized by Torrifluvents, Haplocambids and Haplosalids as the major soil sub groups with 400 to 500 mm rainfall and extends in Firozpur, Faridkot and Bhatinda districts. This is the most productive irrigated sub zone and cotton, sugarcane and paddy are cultivated. Improved varieites, balanced fertilization, development of orchard and sub surface drainage are required to further boost the productivity of this sub zone.

SOUTHERN COASTAL AND BASALT SUB REGION (6.18 m ha 21.7%)

The sub region covers the entire Kachchh, north Saurashtra and Santhalpur plain area. Coastal uplands, mudflats, *ranns* associated with shallow gravelly uplands

of basaltic origin form the physiography of this sub region. Mean annual rainfall has wide spatial variation of 150 to 500 mm. Ground water resources are scarce and brackish. The sub region has integrated drainage system as a result runoff water received through rainfall is drained to sea and area experiences extreme drought condition. The sub region has been divided in four zones and thirteen sub zones.

8. Coastal Saline/rocky upland (3.32 m ha 11.8%)

This zone occurs in Kachchh and Jamnagar districts. There are wide variations in soils viz. Haplosalids, Torrifluvents, Udifluvents, Lithic Orthents, Haplocalcids and Haplocambids. Salt extraction, mangroves and saline grazing land are major non-agricultural land uses. In pockets groundnut is the only rainfed crop. The zone has been subdivided in six sub zone.

8.1 Ranns and mudflats (2.07 m ha 7.3%) : The *ranns* and mudflats with 200 to 300 mm rainfall occur along the coast in Kachchh and Jamnagar districts. These are Haplosalids having high salinity as the result of inundation due to seawater. Saline waste and salt pans is the only landuse. Thechnology for extraction of common salt, improvement of inhospitable environment and energy plantation with salt tolerant bushes is required.

8.2 Banni ecosystem (0.28 m ha 1.0%) : The *banni* grassland with 250 to 300 mm rainfall occur in Kachchh district. These are uplands with shallow Torrifluvents soils interspersed with saline pockets. Grazing is the only landuse but the grasslands are in highly degraded condition. Technology for livestock based grassland improvement is needed.

8.3 Mangrove ecosystem (0.24 m ha 0.8%) : In the Kachchh and Jamnagar districts along the coast with 150 to 200 mm rainfall occur mangrove which have Udifluvents and Haplosalids soils. Because of biotic interference these are in highly degraded condition and needed technologies for their rehabilitation.

8.4 Rocky uplands with limited agriculture (0.28 m ha 1.0%) : This sub zone is characterized by Lithic Orthents soils, 200 to 250 mm rainfall with limited

cropping and occurs in Kachchh district. Shallow soil depth, water erosion and low available water capacity of soils and depleting ground water resources are major constraints. Technologies for silvipasture on the gravelly uplands and for rainfed and irrigated groundnut, castor, wheat and development of orchards of sapota, pomegranate and jujube in valley fills are required.

8.5 Coastal saline plain (0.2 m ha 0.7%) : This sub zone with 200 to 300 mm rainfall includes the Haplosalids in Kachchh and Jamnagar districts which are being used for animal grazing or as saline waste. Salt laden moist breezes from sea make the grasses unpalatable. Livestock based enterprise, identification of salt tolerant grasses and bushes, *in situ* moisture conservation and enhancement of the palatability of grasses are required for development of the area.

8.6 Dwarka coastal plain (0.25 m ha 0.9%) : This sub zone characterized by Lithic Haplocalcids, Petrocalcids and Haplosalids, low rainfall (150-200 mm), scarce surface and ground water and frequent droughts. The sub zone occurs in Jamnagar district. Rainfed groudnut, castor, cowpea are major crops. Constrains associated with this sub zone are frequent droughts, shallow and calcareous soils underlain by petrocalcic horizon and lack of irrigation facilities. Technologies are needed to conserve rainwater to mitigate the adverse effects of frequent droughts, development of orchards of jujube, sapota and pomergranate in valley fill area and silvipastures on non-arable lands. The associated coastal low sand dunes should be vegetated through silvi-pasture.

9. Kachchh alluvial plain (1.06 m ha 3.7%)

The alluvial plain characterized by medium to fine textured moderately deep soils and occurs in Kachchh district. The zone is known for high production of groundnut, cotton, pulses and other horticultural crops. The zone has been classified in two sub zones.

9.1 Central Kachchh plain with valley fill and rocky upland (0.81 m ha 2.8%) : The sub zone is characterized by Haplocambids, Ustertic Haplocambids, Lithic Calcids and Ustipsamments soils with 250 to 300 mm rainfall. The valley fills are very productive and constraints are only due to inadequate irrigation. Tecnologies

are needed for increasing the yields of irrigated crops like groundnut, cotton, sugarcane and wheat and agro-forestry under rainfed condition and silvipasture for the uplands.

9.2 Coastal alluvial plain with intensive irrigation (0.25 m ha 0.9%) : This is the most productive area in this sub region characterized by Haplocambids and Haplocalcids soils, with better rainfall (350-450 mm) and surface and ground water resources. Irrigated cash crops including groundnut and cotton are widely grown. Improved seeds, moisture conservation and agriculture with judicious irrigation are required to boost the crop production.

10. Santhalpur plain with saline soils (0.71 m ha 2.5%)

The zone occurs in the northern part of Gujarat and soils are sandy, medium textured and saline. Rainfall is also low (250-350 mm). Rainfed kharif cropping is the major landuse. The zone has been classified in two sub zones.

10.1 Santhalpur plain with coarse loamy soils (0.55 m ha 1.9%) : The sub zone characterized by Haplocambids and Torripsamments (P) soils and 250 to 350 mm rainfall is spread in Banaskantha, Mehsana and Jalor district. Pearlmillet, groundnut and pulses are major crops. Constraints due to sandy and saline soils, brackish water irrigation and high variability in rainfall limit the yields of kharif crops. Technological support is needed in terms of moisture conservation, agroforestry and management of saline soils/ground water and silvipasture.

10.2 Rapar plain with fine loamy soils (0.16 m ha 0.6%) : The plain characterized by fine textured soils classified as Paleargids and 250 to 300 mm rainfall occurs in Kachchh district. Rainfed sorghum, sesamum and pearlmillet in *kharif* and in irrigated pockets of castor and wheat in *rabi* are major crops. Scarce water resources, high salinity in soils and ground water and fine texture of soils pose serious constraints. Technologies to conserve rain water, agro-forestry and silvi-pasture involving salt tolerant bushes are needed to improve crop yields.

11. Basaltic piedmont plain (1.1 m ha 3.8%)

The zone extends in major part of Jamnagar and in parts of Rajkot and Junagarh districts and has moderately undulating basaltic terrain. Soils at the crest and slopes of uplands are shallow, eroded, gravelly Lithic Ustorthent, whereas in piedmont plain and valley fills Vertic Ustochrepts and Typic Haplusterts are encountered. Groundnut is the major crop on all types of soils both under rainfed and irrigated conditions, which is followed by castor, cotton, spices and wheat in valley fills.

11.1 Basaltic gravelly rocky upland (0.12 m ha 0.4%) : Open grazing land with shallow, skeletal soils classified as Lithic Orthents, moderate slope, poor surface and groundwater resources with 250 to 350 mm rainfall are the salient characteristics of this sub zone. The sub zone occurs in Jamnagar district. Shallow soil depths, moderate to severe water erosion, high proportion of gravels mixed with the soil are constraints. Improved grassland management, silvipasture and runoff water conservation is required to increase the biomass production.

11.2 Basaltic piedmont plain with shallow soils (0.18 m ha 0.6%) : The sub zone characterized by moderate to gentle slope, Lithic Ustorthents soils of clay loam to silt clay loam texture and 40 to 50 cm depth receiving 400 to 500 mm rainfall are being cultivated invariably for groundnut both in *Kharif* and *rabi*. Other important irrigated crops are castor, wheat and spices. The sub zone occurs in Jamnagar and Rajkot districts. The associated constraints are low infiltration, cloddiness, sodic soils and brackish water for irrigation. Technologies to over come these constraints are required.

11.3 Basaltic piedmont plain with moderately deep soils (0.81 m ha 2.8%) : The sub zone is characterized by Vertic Ustochrepts and Typic Haplusterts soils, 250 to 400 mm rainfall, moderate surface and ground water resources. Rainfed groundnut, sorghum, pearlmillet and wheat are major crops grown. Lack of irrigation facilities, poor physical characteristics of soils including cloddiness,

low infiltration and lack of irrigation facilities are major constraint. *In situ* moisture conservation, improvement of soil physical properties, judicious use of irrigation water and management of brackish water are the technologies required for sustainable management of this sub zone.

Summary

The northwestern hot arid region of India has been classified in four agro-ecological sub regions, eleven agro-ecological zones and thirty-four agro-ecological sub zones. The sub regions are based on physiography, rainfall and water resources (Surface water through streams, canal and ground water). Within the sub region, agro-ecological zones, have been identified on the basis of landform-soil associations, landuse and cropping pattern. For recognition of agro-ecological sub zones an integrated approach involving landscape; soil texture, depth and salinity; and surface/ground water potential has been adopted. The sub zones are uniform with respect to potentials/constaints for agricultural and silvipasture and will require specific technology for sustainable development.

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Table 1. Agro-ecological sub regions, zones and sub-zones in the north western hot arid Region of India

Agro-ecological zones/sub-zones	Area m ha (%)	Rainfall (mm)	Soils	Landuse/ Major crops	Districts
Western sandy plain sub region					
1. Hyper arid zone					
1.1 Hyper arid	0.86 (3.0)	<100	Torripsamments(D)	Sandy waste	Jaisalmer
2. Dune complex with scrub and grasses					
2.1 Western dune complex with *Lasiurus Sindicus*	2.96 (7.2)	100-150	Torripsamments(D)	Open grazing	Jaisalmer Barmer Bikaner
2.2 Western dune complex with scrub	0.26 (0.9)	100-150	Torripsamments(D)	Open grazing	Barmer
3. Hard pan zone					
3.1 Hard pan soil	1.57 (5.5)	150-250	Petrocalcids Lithic Cambids Lithic Calcids	Limited kharif cultivation, grazing land	Jaisalmer Barmer Jodhpur Bikaner
4. Sandy plain with scattered dunes					
4.1 Eastern dune complex with limited cultivation	1.32 (4.6)	250-350	Torripsamments(D)	Kharif-bajra, moong, moth, Rabi-Gram	Bikaner Churu Sikar Jhunjhunu
4.2 Sandy plain with <300 mm rainfall	3.68 (12.9)	250-300	Torripsamments(D) Haplocambids Haplocalcids	Khariff-bajra, moth, guar	Barmer Jodhpur Nagaur Bikaner Ganganagar Churu Jalor
4.3 Sandy plain with >300 mm rainfall	0.70 (2.4)	300-450	Torripsamments (P&D)	Kharif-bajra, moong and til	Ganganagar Churu Jhunjhunu Bhiwani

Agro-ecological zones/sub-zones	Area m ha (%)	Rainfall (mm)	Soils	Landuse/ Major crops	Districts
4.4 Sandy plain with inland drainage	1.25 (4.4)	300-400	Torripsamments(P) Haplocambids	Kharif-bajra, moong, Rabi-wheat, mustard	Nagaur Sikar Jhunjhunu
4.5 Western Haryana-Punjab plain	1.01 (3.6)	350-450	Ustipsamments (P&D), Torripsamments (P&D) Haplocambids	Kharif-bajra, moth, moong, til, Rabi-Wheat, mustard	Bhatinda Faridkot Hisar Sirsa
Central alluvial plain sub region					
5. Luni-Banas basin					
5.1 Luni basin with coarse loamy soils	2.67 (9.4)	300-450	Haplocalcids Haplocambids	Kharif-bajra, guar, moong, til Rabi-cumin, mustard, wheat, isabgol with brackish water rrigation	Nagaur Pali Jodhpur Jalor Barmer Banaskantha
5.2 Luni basin with fine loamy soils	1.44 (5.0)	300-450	Haplocambids Haplocalcids Haplosalids	Kharif-bajra, jowar, til, maize Rabi-wheat, mustard, cotton	Pali Jalor Nagaur Jodhpur
5.3 Mendha basin	0.17 (0.6)	400-450	Torripsamments (P) Torrifluvents Haplocambids Haplosalids	Kharif-cotton Rabi-wheat, mustered, spices	Sikar Nagaur
5.4 Aravalli foot hill	0.76 (2.6)	450-500	Lithic cambids Haplocambids	Kharif-maize, jowar, til, cowpea	Jhunjhunu, Sikar, Pali Jalor, Nagaur
5.5 Aeo-alluvial plain of Banas	0.07 (0.2)	450-500	Ustipsamments	Kharif-bajra, pulses, castor, Rabi-wheat cumin isabgol	Banaskantha
5.6 Sabarmati plain	0.34 (1.2)	400-500	Haplocambids Ustipsamments (P)	Kharif-maize, jowar, groundnut, castor Rabi-wheat, mustard spices	Banaskantha Mehsana

Agro-ecological zones/sub-zones	Area m ha (%)	Rainfall (mm)	Soils	Landuse/ Major crops	Districts
Northern canal irrigated sub region					
6.0 Canal irrigated sandy plain					
6.1 Dune complex with canal irrigation	1.18 (4.1)	150-250	Torripsamments (D) Petrogypsids Petrocalcids	Sand dunes- silvipasture inter dunes wheat, mustard, groundnut	Jaisalmer Bikaner
6.2 Aeolian plain of north-east	0.55 (1.9)	250-300	Torripsamments (P) Haplogypsids	Kharif-bajra, guar, cotton Rabi-wheat, mustard	Ganganagar Sirsa Faridkot
6.3 Gaggar flood plain	1.06 (3.7)	250-300	Torrifluvents Torripsamments (P) Haplosalids	Kharif-cotton, wheat, paddy, sugarcane	Ganganagar Firozpur Faridkot
7. Canal irrigated alluvial plain					
7.1 Sutlej plain with coarse loamy soils	0.54 (1.9)	400-450	Ustipsamments (P)	Rainfed-bajra, gram Rabi-wheat paddy	Firozpur Faridkot Bhatinda Hisar
7.2 Yamuna plain with loamy soils	0.51 (1.8)	450-500	Haplocambids Ustorthents Ustochrepts	Kharif-maize, urd, jowar Rabi-wheat, paddy sugarcane, gram	Sangrur Hisar Jind Bhiwani
7.3 Sutlej plain with fine loamy soils	0.37 (1.3)	400-500	Torrifluvents Haplocambids Haplosalids	Sugarcane, cotton, paddy, wheat, mustard	Firozpur Faridkot Bhatinda
Southern coastal and basalt sub region					
8. Coastal saline / rocky uplands					
8.1 Rann and mudflats	2.07 (7.3)	200-300	Salids	Saline waste salt pan	Kachchh Jamnagar
8.2 Banni ecosystem	0.28 (1.0)	250-300	Torrifluvents	Open grazing salt waste	Kachchh Jamnagar
8.3 Mangrove ecosystem	0.24 (0.8)	150-200	Udifluvents/Salids	Mangroves	Kachchh Jamnagar

Agro-ecological zones/sub-zones	Area m ha (%)	Rainfall (mm)	Soils	Landuse/ Major crops	Districts
8.4 Rocky upland with limited agriculture	0.28 (1.0)	200-250	Lithic Orthents	Kharif-bajra, pulses, limited cropping	Kachchh
8.5 Coastal saline plain	0.20 (0.7)	200-300	Salids	Open grazing Saline waste	Kachchh Jamnagar
8.6 Dwarka coastal plain	0.25 (0.9)	150-200	Lithic Haplocalcids Haplosalids Petrocalcids	Rainfed-groundnut, castor cowpea, jowar	Jamnagar Junagarh
9. Kachchh alluvial plain					
9.1 Central plain with valley fill and rocky upland	0.81 (2.8)	250-350	Haplocambids Ustipsamments Ustertic Haplocambids Lithic Calcids	Limited irrigation groundnut, cotton, jowar pulses horticulture	Kachchh
9.2 Coastal alluvial plain with intensive agriculture	0.25 (0.9)	350-450	Haplocambids Haplocalcids	Extensively irrigated groundnut, cotton, pulses	Kachchh
10. Santhalpur plain with saline soils					
10.1 Santhalpur plain with coarse loamy soils	0.55 (1.9)	250-350	Torripsamments (P) Haplocambids	Rainfed groundnut, til, castor saline waste	Banaskantha Mehsana Jalor
10.2 Rapar plain with fine loamy soils	0.16 (0.6)	250-350	Paleargids	Rainfed jowar til, bajra, castor Rabi-wheat	Kachchh
11. Basaltic piedmont plain					
11.1 Basaltic gravelly/rocky upland	0.12 (0.4)	250-350	Lithic Orthents	Limited rainfed grounnut, open grazing	Jamnagar
11.2 Basltic piedmont plain with shallow soils	0.18 (0.6)	400-500	Lithic Ustorthents	Limited irrigation groundnut, spices	Jamnagar Rajkot
11.3 Basaltic piedmount plain with moderately deep soils	0.81 (2.8)	250-400	Vertic Ustocherpts Typic Haplusterts	Groundnut, cotton sugarcane, spices	Jamnagar Junagarh Rajkot

Table 2 : Development block/tehsil/taluk covered under different agro-ecological sub-zones of hot arid ecosystem

Agro-ecological sub-zones		State/District	Tehsil/taluk
Western Sandy Plain Sub-Region			
1.1	Hyper arid	**Rajasthan** Jaisalmer	 Sam
2.1	Western Dune complex with *Lasiurus sindicus*	Jaisalmer Barmer	Sam, Jaisalmer Sheo
2.2	Western Dune complex with scrub	Barmer	Chohtan, Ramsar
3.1	Hard pan zone	Jaisalmer Barmer Jodhpur Bikaner	Jaisalmer, Pokaran Sheo, Barmer Phalodi Kolayat
4.1	Eastern dune complex with limited cultivation	Churu Bikaner Sikar	Dungargarh, Sardarshahr, Ratangarh, Churu,Nokha, Lunkaransar, Bikaner Fatehpur Sekhawati
4.2	Sandy plain with less than 300 mm rainfall	Barmer Jalor Jaisalmer Jodhpur Nagaur Bikaner Ganganagar Hanumangarh	Chohtan, Guda Malani, Barmer, Baytu, Sheo Sanchor Pokaran Shergarh, Phalodi, Osian Nagaur Nokha, Bikaner, Lunkaransar Suratgarh Rawatsar, Nohar
4.3	Sandy plain with more than 300 mm rainfall	Churu Hanumangarh **Haryana** Bhiwani	Taranagar, Rajgarh Bhadra, Nohar Loharu, Charkhi Dadri, Bhiwani, Toshana, Siwani
4.4	Sandy plain with inland drainage	**Rajasthan** Nagaur Churu Sikar Jhunjhunu **Haryana** Mahendragarh	 Didwana, Jayal, Degana, Parbatsar, Ladnu Sujangarh Lachhmangarh, Sikar, Fatehpur Jhunjhunu, Chirawa, Nawalgarh Mahendragarh

Agro-ecological sub-zones		State/District	Tehsil/taluk
4.5	Western Haryana-Punjab plain	**Rajasthan**	
		Hanumangarh	Nohar, Bhadra
		Haryana	
		Sirsa	Sirsa, Dabwali
		Hisar	Hisar, Fatehabad
		Bhiwani	Bhiwani, Charkhi Dadri
		Punjab	
		Faridkot	Malant, Lambi
		Bhatinda	Bhatinda, Sangat, Talwandi Sabo, Jhunir
Central Alluvial Plain Sub-Region			
5.1	Luni basin with coarse loamy soils	**Rajasthan**	
		Jalor	Sanchor, Raniwara, Bhinmal, Jalor, Ahor
		Barmer	Sindhri, Siwana, Pachpadra
		Jodhpur	Jodhpur, Osian, Bhopalgarh, Shergarh
		Pali	Rohat
		Nagaur	Nagaur, Jayal
		Gujarat	
		Banaskantha	Deoda, Tharad, Kankrej
5.2	Luni basin with fine loamy soils	**Rajasthan**	
		Jalor	Ahor
		Pali	Bali, Pali, Sojat, Raipur, Jaitaran
		Jodhpur	Bilara, Bhopalgarh
5.3	Mendha basin	Nagaur	Merta, Nagaur, Jayal, Degana, Parbatsar, Nawa
		Sikar	Danta Ramgarh, Ringas, Sri Madhopur
5.4	Aravalli foot hill	Jhunjhunu	Khetri, Udaipur-Wati
		Sikar	Sikar, Danta Ramgarh, Ringas, Neem-ka-Thana
		Nagaur	Nawa, Parbatsar
		Pali	Raipur
		Sirohi	Mandar, Sirohi, Reodar
5.5	Aeo-alluvial plain of Banas	**Gujarat**	
		Banaskantha	Disa, Dhanera
		Mehsana	Patan
5.6	Sabarmati plain	Banaskantha	Palanpur, Vadam
		Mehsana	Patan, Hanif, Chanasma
		Surendranagar	Dasada, Lakhtar
		Ahmedabad	Mandal, Viramgam

Agro-ecological sub-zones		State/District	Tehsil/taluk
Northern Canal Irrigated Sub-Region			
6.1	Dune complex with canal irrigation	**Rajasthan**	
		Jaisalmer	Nachna
		Bikaner	Bikaner, Kolayat, Lunkaransar
		Ganganagar	Gharsana, Anupgarh, Bijainagar, Suratgarh
6.2	Aeolian plain of north-east	Ganganagar	Suratgarh
		Hanumangarh	Pilibanga, Hanumangarh, Tibi, Sangaria, Rawatsar, Nohar
		Haryana	
		Sirsa	Ellenabad, Dabwali, Rania
6.3	Ghaggar flood plain	**Rajasthan**	
		Ganganagar	Gharsana, Anupgarh, Bijainagar, Suratgarh, Raisinghnagar, Padampur, Ganganagar, Sadulshahr
		Hanumangarh	Pilibanga, Hanumangarh, Sangaria
		Punjab	
		Firozpur	Abohar, Fazilka, Khujan Sarwar
		Faridkot	Lambi, Malant
7.1	Sutlej plain with coarse loamy soils	Firozpur	Fazilka
		Faridkot	Muktsar, Malant
		Bhatinda	Nathwana, Rampura Phul, Mansa, Budhlada, Bhatinda
		Haryana	
		Hisar	Ratia
		Punjab	
		Sangrur	Barnala, Sunam
7.2	Yamuna plain with loamy soils	Sangrur	Sunam, Barnala
		Bhatinda	Budhlada
		Haryana	
		Hisar	Tohana, Dhansi, Narnaund
		Bhiwani	Bhawani Khera
7.3	Sutlej plain with fine loamy soils	**Punjab**	
		Firozpur	Firozpur Zira Jalalabad, Gura Harsahai, Ghall Khurd, Dharamkot
		Faridkot	Kot Kapura, Faridkot, Moga, Nihalsinghwara
		Bhatinda	Phul
		Sangrur	Barnala

Agro-ecological sub-zones		State/District	Tehsil/taluk
Southern Coastal and Basalt Sub-Region			
8.1	Rann and mud flats	**Gujarat** Kachchh	 Great and little rann of Kachchh
8.2	Banni ecosystem	Kachchh	Bhuj
8.3	Mangrove ecosystem	Kachchh Jamnagar	Abdasa, Lakhpat, Anjar Khambhaliya, Jamnagar, Jodia
8.4	Rocky upland with limited agriculture	Kachchh	Lakhpat, Bhuj, Rapar, Bhachhau, Abdasa
8.5	Coastal saline plain	Kachchh Jamnagar Rajkot	Mandvi, Mundra, Abdasa, Anjar Okhamandal, Jamnagar, Jodia Maliya
8.6	Dwarka coastal plain	Jamnagar Junagarh	Okhamandal, Kalyanpur Porbandar, Ranavav
9.1	Central plain with valley fill and rocky upland	Kachchh	Abdasa, Nakhtarana, Bhuj, Anjar, Bhachau, Rapar
9.2	Coastal alluvial plain with intensive agriculture	Kachchh	Anjar, Mandvi, Mundra
10.1	Santhalpur plain with coarse loamy soils	Banaskantha Mehsana Surendranagar	Tharad, Randhanpur, Santhalpur, Deodar, Kankrej Sami, Harij Dasada, Dhrangadhra
10.2	Rapar plain with fine loamy soils	**Rajasthan** Jalor **Gujarat** Kachchh	 Sanchor Rapar, Bhachhau
11.1	Basaltic gravelly/rocky upland	Jamnagar	Lalpur, Bhanwad, Kalawad
11.2	Basaltic piedmont plain with shallow soils	Jamnagar Rajkot	Kalawad, Dhrol, Jamnagar Pada Dhari, Wankaner, Upleta
11.3	Besalti piedmont plain with moderately deep soils	Jamnagar Junagarh Rajkot	Kalyanpur, Khambhaliya, Jamnagar, Jodia, Dhrol, Bhanwad, Jam Jodhpur, Lalpur Manavdar, Kutiyana, Ranavav, Porbandar Morvi, Maliya, Wankaner

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