Annals of Arid Zone 40(2): 141-153, 2001

Integration and Assessment of Biophysical Resources of Sikar District for Sustainable Land Use Planning

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Abstract: In Sikar district, 18 Major Land Resources Units (MLRUs), having homogeneity of biophysical resources such as landform, soil, vegetation, surface and ground water and present landuse, were identified, characterized and assessed for their potentialities and limitations. Information on each resource unit was further evaluated and assessed for sustainable landuse planning and development in the district. The land resources units, qualifying for land capability classes IIc and IIIc, having 3388 km^2 (43.38%) area, low intensity of degradation and reasonably good quality of water, are most suitable for both rain-fed farming with agroforestry system and irrigated farming with agrohorticulture system. The marginal lands with capability class IVc, suffering from various land degradation hazards, having 2086 km^2 (26.97%) area, and poor ground water potential, are suitable for agroforestry, pasture and silvi-pastoral systems. The remaining 2258 km^2 (29.20%) area, not suitable for cultivation due to soil depth, wind and water erosion, high salinity and waterlogging, could be developed for silvopasture using salt-tolerant plant species and for salt extraction.

Key words: Major Land Resource Units, land degradation hazards, resource potential, wind erosion/sand deposition, agro-horticulture, agroforestry, pasture.

It is an established fact that for the rational integrated landuse planning and management of different arid ecosystems, appraisal and assessment of their climatic conditions and biophysical resources are of paramount importance. In view of this, the integrated biophysical resources survey, involving landform, soil, vegetation, surface and ground water resources and land use in the arid region of India are being conducted in various administrative blocks, districts, river basins and clusters of villages for the last four decades by a multidisciplinary team of scientists of Central Arid Zone Research Institute (CAZRI), Jodhpur. The above resources are compiled and integrated in the form of reports using the concept of Major Land Resources Units (MLRUs) for rational land use planning (Abichandani et *al.*, 1975a and b; Anon., 1982; Shankarnarayana and Kar, 1983; Chatterji and Kar, 1989, 1992; Singh *et al.*, 1995, 1997).

Realising the significance of the potential and limitations of biophysical resources in regional development planning, semi-detailed integrated biophysical resources survey, using remote sensing techniques and ground truth, was carried out in Sikar district by a team of subject matter specialists (Singh *et al.*, 1996). The evaluation and assessment of the potential and limitations of the biophysical resources of different MLRUs for their sustainable integrated landuse planning, using suitable control measures, was done and

findings of this study are discussed in this paper.

Geographical Setting

The district under study, covering an area of 7732 km^2, lies in between latitudes 27°10′ and 28° 12′ N and longitudes 74° 40′ and 76° 15′ E in the extreme north-eastern part of arid Rajasthan. The district is characterized by scanty and erratic rainfall, high temperature and high evapotranspiration. The mean annual rainfall is 453.6 mm, varying from 377 mm in the north to 502 mm in the east. Mean maximum and minimum temperatures range from 37 to 42°C and 22 to 26°C, respectively. The annual evapotranspiration ranges from 1500 to 2000 mm. Due to arid climate and low and erratic rainfall, the drainage system is not well integrated and there is no perennial river. However, several ephemeral streams, namely the Kantli, the Dohan, the Krishanawati, the Mendha and the Sabi exist here. The buried courses of palaeodrainage channels with high salinity problem are existing in the southern part of Danta Ramgarh tehsil. Physiographically, the district could be divided into flat and sandy undulating alluvial plains, sand dunes, interdune plains, hills and pediments.

Materials and Methods

Before undertaking field survey, pre-field interpretation of remote sensing data, including aerial and space photographs, was done and preliminary boundaries of various resources were delineated. Semi-detailed integrated natural resources survey of landform, soil, vegetation, surface and ground water and landuse was carried out by a team of subject matter specialists following the standard survey procedure and methodology, using 1:50,000 scale Survey of India topographical maps and standard geocoded false color composites (1:50,000 scale) of IRS Liss II bands for October and February months. The preliminary boundaries of resources were checked in the field and corrected. The maps were then manually superimposed on each other to draw the boundaries of MLRUs. The areas where common boundaries between landforms and other resources could not be demarcated properly in the first instance, attempts were again made by the concerned specialists for their correct demarcation. After removing the discrepancy, final map showing 18 MLRUs was prepared for sustainable land use planning.

Results and Discussion

Integration and assessment of biophysical resources of MLRUs

Assessment of the physical potentials and limitations of the resources in 18 MLRUs in the district (Table 1 and Fig. 1) revealed that these land resource units will form a sound basis for sustainable landuse planning in Sikar district, using suitable soil and water conservation measures. Moderately deep to deep flat buried pediments with medium to fine textured soils (MLRU-3), very deep flat sandy older alluvial plains with coarse textured soils (MLRU-6), very deep flat older alluvial plains with coarse to medium textured soils and fence line hummocks (MLRU-7), very deep alluvial plains with coarse to medium textured soils (MLRU-8), deep to deep flat older alluvial plains with fine textured soils (MLRU-9) and younger alluvial plains with coarse to medium textured soils (MLRU-12) and wind and water erosion

Table 1. Characteristics of Major Land Resource Units (MLRUs) of Sikar District

MLRU Units and slope per cent	Soils and land use capability	Natural Vegetation	Surface water	Ground water depth (m) EC G. water (dS m^{-1})	Present land use	Area (km^2)
1	2	3	4	5	6	7
Hills (58-70%)	Shallow gravelly and bare rocky surface (VII &VIII)	*Anogeissus pendula, Acacia senegal, Acacia arabica, Wrightia tinctoria, Maytenu emarginatus*	Insignificant infiltration,high runoff potential, numerous gullies along Aravalli hills,30.87mcm run-off	Nil	Rocky and stony waste, partly forested, subjected to severe water erosion	491
Rocky/ gravelly pedi-ments, 3-5%	Shallow gravelly loamy sand, strongly calcareous, V1 and VII c, Sh, ew.	*Capparis decidua Maytenus emarginatus, Acacia nilotica, Acacia leucophloea*	Density of village tanks 3/100 km^2	11-40 > 2.0	Mainly wastelands used as grazing land.	125
Flat buried pediment, 1-2%	Moderately deep to deep, loam to clay loam, moderately calcareous under lain by weathered rock, III & IV c, sh	*Acacia nilotica, Azadirachta indica, Acacia leucophloea, Balanites aegptica, Maytenus emar-ginatus*	13-village tanks of 0.416 mcm storage capacity	11-40 > 2.0	Mono-cropping land with 60 to 80% cropping intensity	227
Undulating buried pediments, 5-15%	Very deep, fine sand to loamysand, non to moderately calcareous underlain by buried rock, VI c, s, ea,ew	*Leptadenia pyrotechnica, Calotropis procera, Saccharum bengalenses, Maytenuse marginatus Acacia senegal*	Good runoff potential, four village tanks with 2/100 km density	No well Nil	Mono-cropping, 30 to 60% cropping intensity	165
Sandy undulating older alluvial plains, 1.5-5%	Very deep sand to loamy sand, non to strongly calcareous, deep sandy, IV c, s, ea	*Prosopis cineraria, Tecomella undulata, Leptdenia pyrotechnica, Calotropis procera, Maytenus amarginates*	414 village tanks, density 23/100 km^2 capacity 27.87 mcm	30-60 2.0-6.0	Mono-cropping with 30 to 80% cropping intensity; double cropping in pockets	1003

Table contd..

1	2	3	4	5	6	7
Very deep, coarse textured soils, 1-2%	Very deep sand to loamy sand, non to strongly calcareous solum and substrata, III c, ea	*Prosopis cineraria, Tecomella undulata, Ziziphus mauritiana, Acacia senegal, Capparis decidua, Saccharum bengalenses* .	414 village tanks, 27 to 87 mcm storage capacity	2.0-6.0 2.0-6.0	Mono & double ·ropping with 80 to 100 and 60 to100% cropping intensity	1319
Very deep, coarse to medium textured soils with fence line hummocks, 1-2%	Very deep loamy sand to sandy loam, non to moderately calcareous, III c, ea	*Prosopis cineraria, Tecomella undulata, Ziziphus mauritiana, Balanites aegytiaca, Acacia leucophloea*	Poor runoff potential, village tanks 3/100 km^2	2.0-6.0 4.0-6.0	Monocropping with 80 to 100% cropping intensity and double cropping in patches	586
Very deep coarse to medium textured soils, >1%	Very deep, loamy sand to sandy loam, non calcareous, III c	*Prosopis cineraria* associated with *Ziziphus mauritiana, Balanites aegyptica*	Poor to moderate run-off potential, five -village tanks with storage capacity 0.1mcm.	11-40 4.0-6.0	Mono cropping & double cropping with 80 to 100% cropping intensity.	603
Deep to very deep fine textured soils, >1%	Deep to very deep loam to clay loam and sandy clay loam with noncalcareous solum and strongly calcareous substrata, II and IIIc.	*Prosopis cineraria,* associated with *Acacia nilotica, Tecomella undulata, Ziziphus mauritiana*	Moderate runoff potential, 457 village tanks with 14.63 mcm storage capacity	11-40 4.0-6.0 & 2.0-4.0	Mono cropping with 80 to 100% cropping intensity and permanent pasture in pockets	390
10-Dissect-ed flat older alluvial plains, 1-2%	Deep sandy loam to loam with non calcareous solum and strongly calcareous substrata, III c, ea and VII c, gu	*Capparis decidua, Leptadenia pyrotecnica, Saccharum bengalenses*	High runoff potential, highly gullied 288 village tanks with storage capacity 12.80 mcm and density 2/100 km^2	10 to 40 > 2.0	Monocropping, with 60 to 80% cropping intensity, gullied wastelands used for graz·ing	325

Table contd...

1	2	3	4	5	6	7
Saline flat older alluvial plains, >1%	Moderately deep to deep loam to clay loam/silty clay loam, strongly calcareous underlain by hard zone of lime concretion with high salinity (VI c sa ew)	*Ziziphus nummalaria*, *Prosopis juliflora*, *Capparis decidua*	High runoff potential 10 village tanks with density of 10/100 km^2 and 0.32 mcm storage capacity	11-30 2.0-8.0	Grazing lands of open pasture	193
Younger alluvial plains, 1-3%	Fine sand to loamy sand, sandy loam to loam and silt loam, non to strongly calcareous, II and III c, s	*Acacia nilotica*, *Acacia jacquemontii*, *Prosopis cineraria*, and *Prosopis juliflora*	Moderate runoff potential, no tanks	8-20 2.0-6.0	Dominantly double cropped and mono cropping in pockets with 60 to 80% cropping intensity	263
Saline younger alluvial plains, 0.5-3%	Deep saline soils with loamy sand, sandy loam and silt loam texture, moderate to strongly calcareous, 1V & V1c, sa, ew	*Prosopis juliflora*	Low runoff potential, no village tanks	10-30 2.0-34.0	Monocropped with 60 to 80% cropping intensity	34
Sanddune, 5-9%	Very deep sand to fine sand, non to strongly calcareous, VI c, ea	*Prosopis cineraria*, *Tecomella undulata*, *Acacia senegal* and Grass	No runoff and village tank	Nil Nil	Sandywaste, monocropped with < 30% cropping intensity on slope of dunes	1237

Table contd..

1	2	3	4	5	6	7
Flat inter dune plains, 1-5%	Very deep sand to loamy sand and sandy loam underlain by loose sandy to strongly well developed thick zone of lime concretions/ gypsum, strongly clcareous, IV c and VI c, ea	*Prosopis cineraria*, *Tecomella undulata*, *Leptodenia pyrotecnica*, *Capparis decidua*, *Ziziphua nummularia*	Moderate runoff potential, 400 village tanks of 12.80 mcm water storage capacity	30-40 2.0-6.0	Monocropping 30 to 60% cropping intensity and grazing lands.	382
Sandy undulating inter dune plains, 1-5%	Very deep sandy to loamy sand, non to strongly calcareous with weak to strong lime concretions zone below 2 to 3 m, IV & VI c, s, ea	*Prosopis cineraria*, *Tecommella undulata*, *Capparis decidua*, *Leptadenia pyrotecyhnica*, *Ziziphus nummularia*	Poor runoff potential and no village tank	30-50 2.0-4.0	Monocropping with 30 to 60 and 60 to 80% cropping intensity	177
Saline-depression, <1%	Very deep clay loam to silty clay loam andsiltyclay, strongly calcareous and saline, VIII c, sa, w	*Suaeda fruticosa* Hallophytic spp.	Rains and runoff water inundation	<10 m > 40	Uncultivated saline waste used for salt extraction	16
River beds, <3%	Gravelly sand to coarse sand, non-33333 Calcareous, VII c, s, ew	*Prosopis juliflora* *Acacia nilotica* *Acacia cupressiformis* and *Prosopis cineraria*	Runoff rain water flow during rainy season.	8 to 20 > 2 .0	Mono and double cropping in pockets	196

subclasses, occupy 3388 km^2 (43.38%) area and have better groundwater and agricultural potentials, as well as less severe wind and water erosion and salinity hazards. Hence, these are the best land resources units in the district, qualified for land capability class IIc and IIIc and fit for both rainfed and irrigated farming with 60 to 80% and 80 to 100% cropping intensity, and are dominantly double cropped areas.

Younger alluvial plains with coarse to medium textured soils (MLRU-12) have good quality of ground water at shallow depth with minimum risk of secondary salinization. This resource unit requires minimum soil and water conservation measures and is fit for double cropping if brought under irrigated

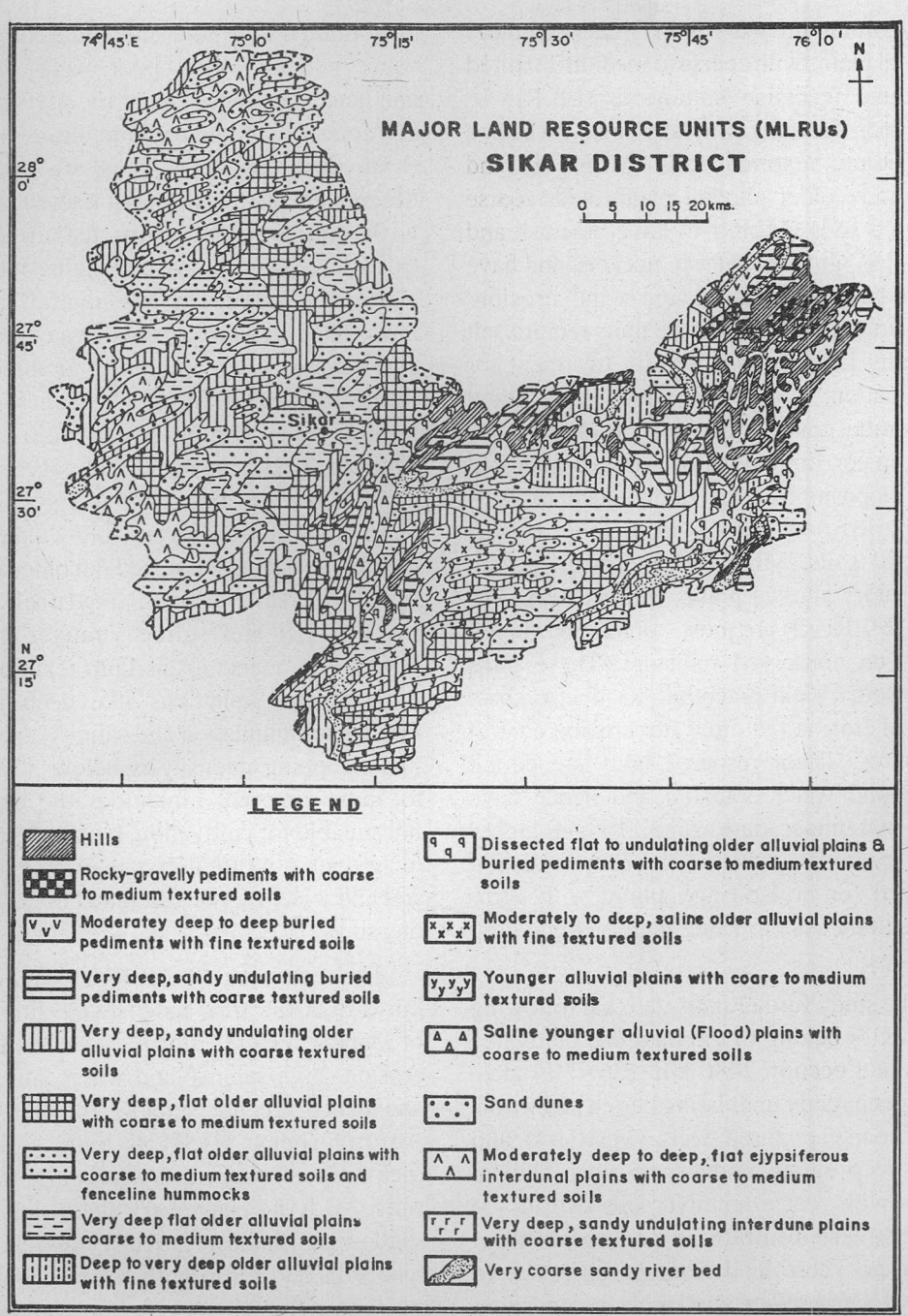

Fig. 1. Major land resource units (MLRUs) of Sikar district.

agro-horticulture system. Very deep flat older alluvial plains with coarse to medium textured soils and fenceline hummocks (MLRU-7), very deep flat older alluvial plains with coarse to medium textured soils (MLRU-8) and flat sandy older alluvial plains with coarse textured soils (MLRU-6) have brackish and high-RSC ground water in pockets, and have secondary salinization and wind erosion/deposition problems. These units require salt leaching process and gypsum treatment for reclamation, along with wind erosion/sand deposition control measures. Rainfed lands have major limitations of wind erosion and sand deposition. Moderately deep to deep flat buried pediments with medium to fine textured soils (MLRU-3) and deep to very deep older alluvial plains with fine textured soils (MLRU-9) are most suitable for rainfed crops on conserved moisture. These units have better yield potential, but due to sheet and rill erosion require water erosion control measures. These resource units are deficit in ground water potential and hence have been put under dark zone. To get higher yield potential, these resource units should be used for dryland agriculture with agro-horticulture system using high yielding crop varieties.

The study further indicated that following 6 MLRUs belong to the marginal cultivated lands and occupy 2086 km^2 (26.97%) area. Very deep sandy undulating buried pediments with coarse textured soils (MLRU-4) and very deep sandy undulating older alluvial plains with coarse textured soils (MLRU-5) have severe limitations for agricultural practices. These land resource units due to severe to very severe wind erosion/deposition and water erosion, low water retention capacity, very poor fertility status, 30 to 60% rainfed crop intensity and poor ground water potential have poor yield potential and hence are better suited for silvi-pastoral, agroforestry and agro-horticulture systems than that of pure crop cultivation. Moderately deep to deep flat interdune plains with coarse to medium textured soils (MLRU-15) and sandy undulating interdune plains are located in low rainfall zone (, mm), have brackish ground water potential and severe wind erosion/sand deposition limitations with frequent occurrence of famine and crop intensity below 30%. Therefore, the pasture and silvopasture systems are the best land use systems for these units, along with suitable wind erosion control measures. Dissected flat older alluvial plains with medium textured soils (MLRU-10) and saline younger alluvial plains with coarse to medium textured soils have severe limitations like deep gullies, floodwater inundation and salinity, and hence their cropping intensity is below 30%. Due to above physical limitations the units are not suitable for cultivation, but are best suited to agro-silvo-pastoral system using extensive soil and water conservation and flood control measures.

The remaining six MLRUs occupy 2258 km^2 (29.20%) area, have severe limitations of depth, texture, slope, water and wind erosion, high salinity and water inundation, and hence are not suitable for cultivation. Among these MLRUs, bare hills and rocky/gravely pediments with coarse textured soils (MLRU-2) have very steep slope, very shallow to shallow gravelly miscellaneous type soils and rill to gully erosion and these are serious impediments for cultivation. Sand dunes and dune complex with loose and structureless sandy soils (MLRU-14) are

severely prone to wind erosion, have poor fertility status, and are not suitable for regular cultivation. Moderately deep to deep saline older alluvial plains with fine textured soils (MLRU-11) have high salinity and higher content of soluble salts, hard lime-rich substrata, water erosion and rain water inundation problem, and hence are not suitable for cultivation. Saline depression (Rann) (MLRU-17) has very fine textured saline soils, highly saline shallow ground water, waterlogging and high salinity problems and hence is fit for salt extraction and pasture development using salt-tolerant grasses. River beds (MLRU-18) have very coarse sand and suffer from severe bank cutting, water erosion and sand deposition. All these land resources units suffer from various degradational hazards and require very high inputs for their reclamation and management.

Suggested integrated land use planning of MLRUs

Despite the implementation of many development programmes during last few decades, the degradation of ecosystems in arid region of Rajasthan is still continuing. Hence, integrated landuse planning and management of biophysical resources in all the MLRUs is absolutely necessary. In farming systems, sustainable production system can be realized by putting equal emphasis on the various resources and farmers' condition, and ensuring farmers' participation in sustainable landuse planning (Singh and Chauhan, 1993; Singh *et al.*, 1997). Ultimately, the production system could be safely based on integrated resource inventory, i.e., land capability, which obviously is desirable for sustainability of the system. However, it can not be thrust upon the farmers for obvious reason. Hence, there is a need for step by step approach in a farming perspective. It is needless to emphasize that biophysical potential and limitations of various MLRUs mapped and evaluated will form a sound basis for rational integrated land use planning of the district (Fig. 2).

Among the MLRUs with high crop intensity (80 to 100%, 100% and above) younger alluvial plains with coarse to medium textured soils (MLRU-12), which have good quality ground water, better soil fertility and potentiality for crop production, should be developed and managed on integrated watershed management basis (Singh and Kar, 1997), using seeds of high yielding and improved crop varieties, adopting proper method of cultivation, soil and water conser- vation measures like wind breaks, wind strip cropping, contour and field bunds, adding of FYM and tank silt to improve the water holding capacity in coarse textured soils and amendments where water is brackish (Fig. 2). The use of pesticides, fertilizers and cultural practices will boost the yield potential if irrigated agro-horticulture crops are taken (Sharma *et al.*, 1986).

Moderately deep to deep flat buried pediments with medium to fine textured soils (MLRU-3), deep to very deep flat older alluvial plains with fine textured soils (MLRU-9) and moderately deep to deep flat interdune plains with coarse to medium textured soils (MLRU-15), presently being used under rainfed crop cultivation on conserved moisture, require almost similar types of crop cultivation and control measures

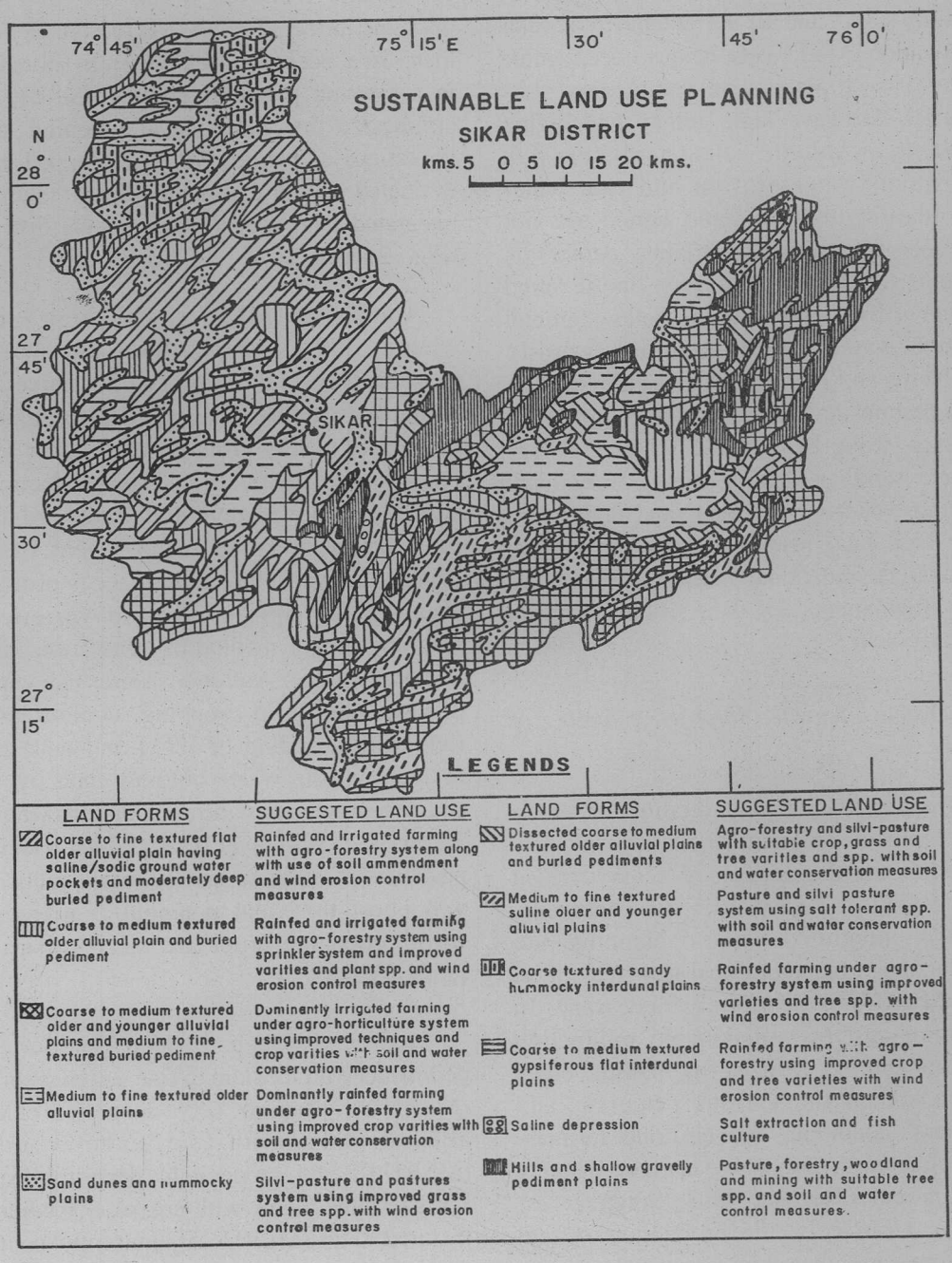

Fig. 2. Sustainable land use planning Sikar district.

as stated above, but need field bunds and vegetative barriers to protect the land from sheet and rill erosion and to check bank cutting (Sharma *et al.*,1986). It has been observed that due to irrigation by moderately brackish and high-RSC ground water the problem of salinity and sodicity has developed in very deep flat older alluvial plains with coarse textured soils (MLRU-6), very deep flat older alluvial plains with coarse to medium textured soils and fenceline hummocks (MLRU-7), and flat older alluvial plains with coarse to medium textured soils (MLRU-8). For the reclamation and improvement, the affected areas of these units should be treated with gypsum as per gypsum requirement of soils (5 to 6 t ha^{-1}), along with soil and water conservation measures like construction of field bunds, deep ploughing, contour bunds, mixed cropping, shelterbelts and vegetative barriers, besides the use of salt-tolerant varieties of crops, pesticides, organic and inorganic amendments (Singh *et al.,* 1997). The field bunds will arrest the rainwater and leach out the soluble salts accumulated due to saline groundwater irrigation. Drip and sprinkler irrigation will reduce the risk of salinization and will save the wastage of water (Fig. 2). The above measures will improve the yield potential and protect the soil health (Singh *et al.,* 1996).

Marginally cultivated aeolian landforms with 30 to 60% crop intensity include very deep sandy undulating buried pediments with coarse textured soils (MLRU-4), very deep sandy undulating older alluvial plains with coarse textured soils (MLRU-5) and undulating interdune plains with coarse textured soils (MLRU-16) that have poor quality ground water (brackish), inherent vulnerability to wind erosion/sand deposition and combined wind and water erosion, irregular slope, poor fertility status and moisture regime (Singh *et al.,* 1996). In order to stabilize the production and productivity of these units, hortipasture and agro-horticulture systems may be adopted with proper soil and water conservation measures like wind breaks, shelterbelts, contour furrows, field bunds with vegetative barriers, mulching and tank silt to check the percolation losses (Fig. 2). Since these land resources units are not fit for cultivation, it is suggested that these may be developed for silvopasture, using *Lasiurus sindicus, Cenchrus ciliaris, Acacia tortilis, Prosopis juliflora, Acacia senegal* and *Calligonum polygonoides* species. Marginal lands of dissected flat older alluvial plains with medium textured soils (MLRU-10) and saline younger alluvial plains with coarse to medium textured soils (MLRU-13) have great risk of gully formation and development of salinity and flood hazards. Development of these units needs measures like check dams, anicuts, earthen bunds, contour furrowing and contour bunds along with grass and tree cover on bunds in upper catchment. The interfluves of MLRU-10 could be developed for silvopasture and agro-horticulture with soil and water conservation measures to check degradation. The silvopasture and agro-horticulture systems will also be well suited to MLRU-13 that can improve its yield potential (Fig. 2). Moderately deep to deep saline alluvial plains with fine textured soils (MLRU-11) and saline depressions (MLRU-17) are degraded due to salt accumulation, water inundation and development of shallow ground water table and these could be developed under pasture

and silvopasture, using salt-tolerant grasses and shrubs like *Tamarix articulata, Atriplex nummularia, Prosopis juliflora, Dicanthium annulatum, Sporobolus marginatus* and Chlorosis virgata, using proper soil and water conservation measures, as well as drainage improvement methods. It is suggested that MLRU-17 could also be used for salt extraction and fish culture. Sand dunes with loose sandy soils (MLRU-14) could be developed for pasture and silvopasture system using *Lasiurus sindicus, Cenchrus cilliaris, Acacia tortilis, Prosopis juliflora, Acacia senegal* and *Calligonum polygonoides* plant species. Reactivated crests and flanks of sand dunes could be stabilized and managed using phyto- reclamation techniques developed by CAZRI, Jodhpur, which involve live fencing, mulching in checker board pattern through locally available plant species and planting of trees and grasses in alternate parallel strips (Fig. 2).

Hills (MLRU-1) with steep slope not fit for cultivation could be used only for mining and the waste could be used in cement and lime industries, or for construction of roads and buildings. The unit could be used for water harvesting. Rocky/gravely pediments with coarse textured soils (MLRU-2), having severe limitations of depth, slope, dissection and texture, could be developed for pasture and silvopasture systems using local grass, shrub and tree species with proper soil and water erosion control measures (Fig. 2).

Conclusions

Aerial and satellite remote sensing techniques in conjunction with ground truth, enabled to identify, classify and map 18 MLRUs in Sikar district. Integration, evaluation and assessment of biophysical resources of these MLRUs, which belong to different land capability classes, have been found useful for the integrated sustainable land use planning in the district. Among these MLRUs, very deep to deep flat older alluvial plains with coarse to medium textured soils and younger alluvial plains with coarse to medium textured soils are best suited for rainfed and irrigated crops. Remaining units could be developed for rainfed and irrigated farming, agrohorticulture, agro-forestry, silvopasture and hortipasture, using suitable soil and water conservation measures such as contour bunds, contour furrows, shelterbelts, check dams, anicuts and earthen bunds.

Acknowledgement

Authors are grateful to Dr. A.S. Faroda, Director and Dr. I.C. Gupta, Head, Division of Natural Resources and Environment, CAZRI, Jodhpur, for providing facilities to conduct this study.

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