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Remote Sensing and GIS for Integrated Resource Management Policy-A Case Study in Medak Nala Watershed, Karnataka, India

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Abstract: Agriculture plays an important role in the economic development of Sedam taluk of Gulbarga district of Northern Karnataka. Nearly 80 per cent of the total area is arable and 76 per cent of the total population is engaged in different agricultural activities. Farmers are harvesting single crop in a year. Characterization and analysis of watershed were carried out using IRS 1D PAN + LISS III (merged data), LISS III data and Survey of India topomaps. Geo-referencing of the satellite data and preparation of different thematic layers like, land use/land cover, soil, hydro-geomorphology, drainage, slope etc. were carried out with the help of ERDAS IMAGINE and ArcGIS software. The results of the study revealed that there is ample scope for water harvesting structures and soil conservation practices in the watershed. The agricultural resource plan includes provision of alternate land use practices like agriculture, agro-horticulture, agro-forestry, afforestation, fodder and fuel and dryland horticulture. Information derived in terms of natural resources and their spatial distribution was then integrated with socio-economic data to develop resources action plans. Such plans are very much useful for efficient and sustainable management of natural resources.

Key words: Remote Sensing · GIS · Land use/ land cover · Soil · Water resources · Resource Management · Medak Nala watershed · Karnataka · India

INTRODUCTION

Over exploitation and mismanagement of natural resources have resulted in adverse effects such as land degradation, biomass deterioration and siltation of tanks etc. Increasing food needs of growing population demands the efficient use of natural resources in a comprehensive manner. In addition, the low per capita availability of land, erratic and uneven distribution of rains, undulating topography, improper resource management, traditional cropping programmes and recurrence of droughts having cumulative effect leading to lower productivity and higher risk particularly in dryland farming. This calls for optimum utilization of natural resources by scientific planning and action oriented approach. In this connection, taking the present day importance of watershed development and capabilities of Remote Sensing, GIS and GPS technologies, the present work was carried out with the help of Karnataka State Remote Sensing Applications Centre (KSRSAC), Bangalore, to develop the agriculture resource action plan for the Medak Nala watershed in Sedam taluk of Gulbarga district. Karnataka State, India.

MATERIAL AND METHODS

Study Area: The Medak Nala watershed selected for resources planning under Integrated Watershed Development Programme (IWDP) is in Sedam taluk of Gulbarga district that falls in Northern Dry Agro-climatic

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Table 1: List of the geographic coordinates of the selected ground truth sites in Medak Nala watershed, Sedam taluk, Gulbarga district

Sl. No.	Control point	Nearest village	Land feature	Latitude	Longitude
1	Road intersection	Bennur	Rabi crop (sorghum)	17° 05' 06.21'' N	77° 24' 42.90'' E
2	Tank corner	Kadlapur 1	Land with scrub	17° 03' 49.65'' N	77° 25' 58.20'' E
3	Road bend	Narapalli	Land with scrub	17° 03' 12.01'' N	77° 28' 26.20'' E
4	Settlement	Kadlapur 1	Road diversion	17° 03' 49.05'' N	77° 25' 38.22'' E
5	Road junction	Rabanpalli	Kharif crop (pigeon pea)	17° 03' 40.28'' N	77° 28' 40.98'' E
6	Drainage origin	Rajoli	Kharif crop (black gram)	17° 06' 20.79'' N	77° 24' 38.69'' E
7	Road junction	Gopanapalli	Double crop (green gram + black gram)	17° 04' 10.08'' N	77° 25' 31.25'' E
8	Road bend	Silarkoturga	Land without scrub	17° 02' 28.31'' N	77° 28' 27.69'' E
9	Road intersection	Gopanpalli	Land with scrub	17° 04' 08.70'' N	77° 25' 38.21'' E
10	Settlement	Rabanapalli	Village tank	17° 03' 32.27'' N	77° 28' 40.63'' E
11	Road bend	Silarkoturga	Kharif crop (pigeon pea)	17° 01' 29.80'' N	77° 28' 22.28'' E
12	Settlement	Narapalli	Road junction	17° 02' 35.57'' N	77° 26' 53.33'' E
13	Tank corner	Kadlapur 2	Land with scrub	17° 02' 41.62'' N	77° 25' 54.74'' E
14	Road with tank corner	Kuttapalli	Kharif crop (sunflower)	17° 02' 19.69'' N	77° 25' 09.45'' E
15	Road intersection in forest	Gajlapur	Scrub forest	17° 01' 02.84'' N	77° 25' 35.23'' E
16	Road junction	Silarkoturga	Land with scrub	17° 01' 02.26'' N	77° 28' 29.98'' E
17	Road junction	Yanagundi	Rabi crop (wheat)	16° 54' 24.21'' N	77° 27' 18.15'' E
18	Settlement	Gajlapur	Temple	17° 00' 34.89'' N	77° 27' 24.32'' E
19	Tank corner	Kanagadda	Kharif crop (pigeon pea)	16° 55' 36.76'' N	77° 26' 49.52'' E
20	Settlement	Kanagadda	Road bend	16° 57' 04.69'' N	77° 25' 31.68'' E
21	Road junction	Tulmamdi	Rabi crop (Bengal gram)	16° 56' 47.94'' N	77° 26' 20.40'' E
22	Settlement	Kundrapalli	Road connection	17° 03' 56.02'' N	77° 26' 47.12'' E
23	Settlement	Krishnapur	Temple	16° 58' 18.74'' N	77° 25' 23.52'' E
24	Settlement	Kadlapur 2	Tank	17° 02' 31.02'' N	77° 26' 03.52'' E
25	Road junction	Pakhal	Land without scrub	16° 58' 45.32'' N	77° 26' 06.77'' E
26	Settlement	Kuttapalli	Road bend	17° 02' 16.40'' N	77° 25' 11.74'' E
27	Settlement	Silarkoturga	Tank	17° 01' 14.56'' N	77° 28' 40.53'' E
28	Road junction	Medak	Kharif crop (pigeon pea)	17° 58' 53.03'' N	77° 27' 48.50'' E
29	Settlement	Medak	Road diversion	16° 58' 50.92'' N	77° 27' 57.30'' E
30	Road bend	Shankarajpur	Kharif crop (green gram)	16° 59' 05.70'' N	77° 28' 19.54'' E
31	Settlement	Shankarajpur	Road bend	16° 59' 06.24'' N	77° 27' 21.67'' E
32	Road interjunction	Pakhal	Land without scrub	16° 58' 59.23'' N	77° 25' 34.94'' E
33	Settlement	Pakhal	Road junction	16° 58' 56.56'' N	77° 26' 03.98'' E
34	Road junction	Kundrapalli	Scrub forest	17° 03' 55.43'' N	77° 27' 55.26'' E
35	Settlement	Krishnarajpur	Road interjection	16° 58' 18.05'' N	77° 25' 22.56'' E
36	Settlement	Rajoli	Road bend	17° 06' 21.52'' N	77° 24' 34.26'' E
37	Settlement	Tulamamdi	Tank	16° 57' 04.69'' N	77° 25' 31.68'' E
38	Settlement	Gangavaralapalli	Road bend	16° 56' 53.04'' N	77° 27' 37.10'' E
39	Settlement	Yanagundi	Temple	16° 54' 09.83'' N	77° 27' 07.83'' E
40	Settlement	Lingampalli	Road diversion	17° 05' 37.22'' N	77° 24' 48.55'' E
41	Settlement	Bennur	Road bend	17° 05' 18.64'' N	77° 24' 53.21'' E
42	Settlement	Gopanapalli	Tank	17° 04' 08.62'' N	77° 26' 04.78'' E

Zone of Karnataka. The watershed area lies between 16°52' to 17°55' North latitude and 77°22' to 77°30' East longitude covering an area of 12,139 ha. The watershed comprises 18 villages and the location map of the study area is shown in Fig. 1.

Methodology: Action plan preparation for Medak Nala watershed using Indian Remote Sensing Satellite Imageries of Indian Remote Sensing Satellite (IRS 1D) for two seasons representing *rabi* (Date of Acquisition: December 8 and 10, 2000) and summer (DOA: March 15, 2001) data were used for preparing thematic maps by visual as well as digital interpretation. For *rabi* season, Linear Imaging Self Scanner (LISS-III contains four bands of Blue, Green, Red and Infrared) and Panchromatic (PAN) merged data (sharpened) was used to get the maximum possible information on various earth features at 1:50,000 scale. Summer season data was basically the geo-coded LISS-III image as it was meant only for detecting any changes with respect to seasons. The satellite imagery of IRS 1D PAN + LISS III used for Medak Nala watershed is shown in Fig. 2.

The satellite images of different seasons were geometrically registered to the Survey of India (SOI) topographic sheet (1:50,000) with a pixel size of 23.5 m using nearest neighbour resampling with second order

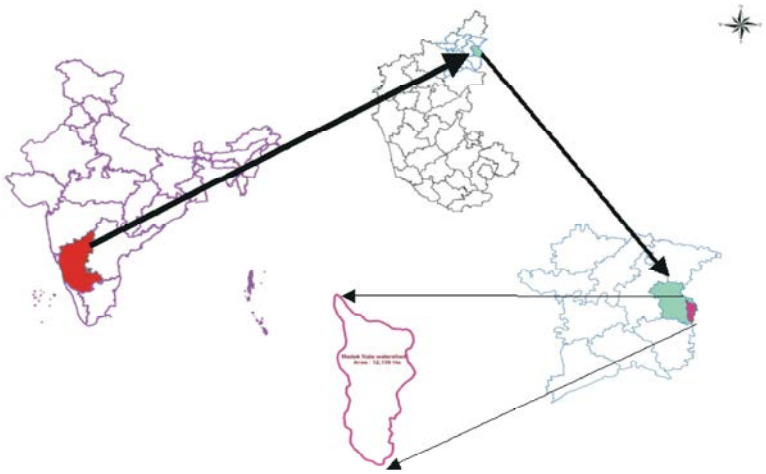

Fig. 1: Location map of Medak Nala watershed, Sedam taluk, Gulbarga district, Karnataka State, India

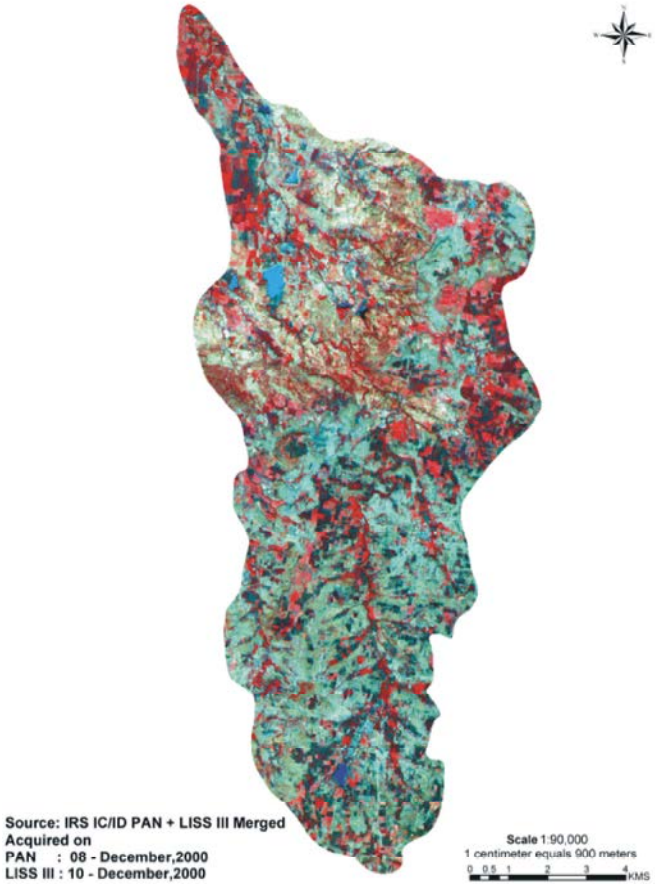

Fig. 2: Satellite imagery of Medak Nala watershed

polynomial equation. The list of ground truth sites selected for the study was given in Table 1. The scenes were clipped to the study area before they were subjected to classification process. Analysis of the multi-temporal satellite datasets includes four major steps of applying atmospheric corrections, delineating training areas, classifying the images and thematic layer preparation [1-3].

RESULTS AND DISCUSSION

The results obtained from thematic mapping of various natural resources such as land use / land cover, geology, soil resource inventory, hydro-geomorphology, slope, drainage, surface water bodies, lineament and other base map information such as transport network and settlement location maps were deduced from topographical information are presented here. The socio-economic and meteorological data was statistically analyzed along with the demand and supply of essential commodities of the watershed for making action plans in more practical and scientific.

Generation of Thematic Layers: The base map containing permanent features like settlements, water bodies, forest lands, road networks etc. was prepared using Survey of Indian toposheets and same was updated using satellite imageries (Fig. 3). The land use / land cover map was prepared using False Colour Composite (FCC) showing the spatial distribution of different land use / land cover categories at 1:50,000 scale and it was up scaled to 1:25,000 scale (Fig. 4). Similar studies were conducted at different places [4-8]. The soils of Medak Nala watershed occur on basaltic and lateritic parent materials and are characterized by different physiographic units [9,10]. In the watershed, 20 soil series were identified and classified up to series level. Taxonomically, the soils were classified under Inceptisols, Alfisols, Vertisols and Entisols. Spatial distribution of soils under varied physiographic settings are mapped and shown in Fig. 5. Rock formations noticed in the watershed are grouped as basalt, laterite, schist, granite and sandstone conglomerate. Slope map was prepared using contour lines, which were derived from the Survey of India toposheets [11-15]. With respect to hydro-geomorphology the watershed has been broadly classified into various geomorphic units, which have been evaluated for their ground water potential. Fig. 6 shows the spatial distribution of different hydro-geomorphic units delineated in the study area. Similar observations were made in different sites [16-19].

Action Plans for Water and Agricultural Resources Development: Action plans for water and agricultural resources development were prepared based on the available resources, requirement of the people and socio-economic conditions. The packages were suggested after careful consideration of prevailing practices and soil productivity.

Water Resources Development Plan: The water resources development plan was suggested for the watershed using the criteria given by NRSA [20] under Integrated Mission for Sustainable Development (Table 2 and 3). The structures suggested for soil and water conservation using drainage map (Fig. 7) was spatially depicted in Fig 8. The water harvesting structures like boulder checks (257), check dams (62), nala bunds (10), minor irrigation tanks (2), soil conservation practices like contour farming, strip cropping and vegetative barriers etc. were suggested. Desiltation of few tanks (26) was the major recommendation in water resources development plan for overall development of water resources. An action plan for development of soil and water resources has been suggested for Medak Nala watershed based on the information obtained from remote sensing and other collateral sources on land use / land cover, slope, terrain characteristics, drainage network, contour lines etc. Non-perennial streams can be exploited by constructing nala bunds, check dams, percolation tanks etc. which improve the ground water conditions and help to bring additional lands under assured irrigation. Similar studies were reported in India [21-24]. The ravine reclamation structures like boulder checks, rubble checks, vegetative barriers etc. help in impounding of water, arresting flow of sediments and help in conservation of water. These structures will recharge the aquifers in the down stream leading to substantial water availability for subsequent second crops and also results in higher yields as reported earlier [25-27].

Agricultural Resources Development Plan: The action plan for agricultural resources development consisting of different alternate land use practices was suggested using the criteria given by NRSA under Integrated Mission for Sustainable Development (Table 4). After considering the current land use / land cover situations, sufficient care was taken not to disturb the existing land use in a large scale so that the suggested land use is technically feasible, economically viable and socially acceptable for the local farming community. Alternate land use practices suggested at micro watershed level (Fig 9) were given in Table 5 and spatially shown in Fig 10. The thematic maps generated using satellite data and topographic maps were

Table 2: Criteria for suggesting soil and water conservation measures in single crop (Kharif /Rabi) and forestlands

Sl. No.	Water resource conservation measures	Land type	Slope %	Other factors
		1Single crop (Kharif/Rabi)		
A	Mechanical measures			
1	Contour bund	All soils except deep clayey soils	6-Jan	Perennial fodders like Styloxanthes hamata are used to stabilize the bunds, where as broad based bunds are suggested in deep clayey soils.
2	Farm pond	All soils except in light textured soils where lining is required	--	Areas where runoff is 10% of precipitation, lower point of natural depressions, diversion ditches add to supplemental drainage.
3	Check bund	All types	Upto 3 Bed slope	Recommended upto 3rd order streams, where water table fluctuation is high, stream is influent and intermittently effluent, minimum of 25 ha. of catchment is desirable, the crest wall of the dam should be strong and well defined.
4	Nala bunds	Relatively permeable soils	< 3.5 Bed slope	Recommended upto 4th order and higher streams, deeper nala facilitates more water-spread area, reduce the velocity of flow.
5	Field bunds with boulders/ pebbles, with soil and live hedge fencing	--	--	Areas where boulders and stones are available, the bund is sprinkled with grass seeds, planted with euphorbia, khus, agave, lantana plantings in the fence, non browsable plants are preferred.
B.	Vegetative measures			
1	Contour farming, strip cropping, ridges and furrows	--	< 3	Less rainfall areas
2	Forests lands			
1	Contour trenches	Soil depth greater than the	Any slope	Scrub forest/plantations, open degraded vegetation, <700 mm rainfall, highly eroded trench depth areas.
2	Staggered trenches, afforestation ditches like V-notch ditches, concave ditches	Shallow soils	> 8	Excessive grazing areas, open degraded vegetation, scrub forest/plantations, bare slopes.
3	Contour stone wall	--	< 3	Where stones, boulders and pebbles are available

Table 3: Criteria for suggesting soil and water conservation measures in double cropped, intensive cropping lands and plantations

Sl No.	Water resource conservation measures	Land type	Slope %	Other factors
		1 Double cropped and Intensive cropping lands		
A	Mechanical measures Check dam	All types	Upto 3 Bed slope	Recommended upto 3rd order streams, where water table1 fluctuation is high, stream is influent & intermittently effluent, minimum of 25 ha of catchment is desirable, the crest wall of the dam should be strong and well defined.
2	Percolation pond	Highly permeable soils	Upto 3	--
3	Nala bund	Relatively permeable soils	< 3.5 Bed slope	Recommended upto 4th order and higher streams, deeper nala facilitates more water-spread area, reduce the velocity of flow.
4	Sub surface dykes	Valleys	--	Bed rock at a depth of 2-5 m.
5	Drains a) Field drains b) Seepage drains c) Carrier drains	Highly permeable soils < 2		Seepage losses from unlined canals, ground water moving from shallow aquifer, non maintenance of natural drainage, uncontrolled irrigation, surface drainage is poor
B.	Vegetative measures			
1	Contour farming, Strip Cropping – Field strip cropping and Contour strip cropping	--	< 3	--
4	Plantations			
1	Bench terrace	Moderately deep soils	> 7	Suitable for growing fruit trees on sloping and undulating lands in thin strips
2	Land leveling & grading	Non shallow soils	Any slope	Must be cost effective, undulated lands with land development like leveling are suitable for commercia1 crops
3	Check dram	All types	Upto 15	Same as above
4	Nala bund	Relatively permeable soils	< 3.5	Same as above

Table 4: Criteria adopted for suggesting alternate land use practices in Medak Nala watershed, Sedam taluk, Gulbarga District

Sl.No.	Soil type	Soil constraints	Slope	Ground water potential	Present land use	Suggested land use
1	Shallow to moderately deep, sandy loam to sandy clay loam	Moderate to strong erosion	Nearly level to moderate slope	Poor to moderate	Kharif	Agro forestry
2	Shallow to moderately deep, sandy loam to sandy clay loam	Imperfectly drained and calcareous	Nearly level to very gentle slope	Moderate to good	Kharif, fallow, scrub	Agro horticulture
3	Shallow to moderately deep, sandy loam to sandy clay loam	Moderate to strong erosion	Gentle slope to moderate slope	Moderate to good	Kharif, fallow	Dryland horticulture
4	Shallow to moderately deep, gravelly sandy loam to sandy loam	Strong erosion	Any	Any	Gullied and ravenous land	Silvi pasture
5	Moderately deep to deep, clay loam to clayey	Calcareousness	Nearly level to very gentle slope	Good	Kharif	Intensive agriculture
6	Rocky land	--	Any	Any	Stony waste, sand	Quarrying
7	Very shallow to shallow, gravelly sandy loam to sandy	Degraded lands and calcareousness	Any	Any	Scrub, salt affected and fallow land	Fodder and fuel
8	Moderately deep to deep, clay loam to clayey	Imperfectly drained and calcareous	Any	Any	Double crop	Double crop
9	All	Stony waste and rocky areas	Any	Any	Forest	Forest plantation
10	Moderately deep to deep, clay loam to clayey	Calcareousness	Nearly level to very gentle slope	Good	Double crop	Sericulture
11	All	Moderate erosion	Nearly level to very gentle slope	Poor to moderate	Agriculture plantation	Agriculture plantation
12	Calcareous soils	Salt affected areas	--	--	Salt affected land	Reclamation / Green manuring
13	Sandy areas	--	--	--	Sand	Sand mining

Table 5: Alternate land use practices suggested for micro-watershed units of Medak Nala watershed, Sedam taluk, Gulbarga District

Sl. No.	Micro-watershed	Suggested alternate land use practices
A	4D5B4B1A	Agro-horticulture, dryland horticulture and intensive agriculture
B	4D5B4B1B	Agro-horticulture, dryland horticulture and fodder & fuel
C	4D5B4B1C	Agro-forestry, agro-horticulture and dryland horticulture
D	4D5B4B1D	Dryland horticulture, agro-horticulture and intensive agriculture
E	4D5B4B1E	Dryland horticulture, agro-horticulture, fodder & fuel and intensive agriculture
F	4D5B4B2F	Agro-horticulture, fodder & fuel, dryland horticulture and intensive agriculture
G	4D5B4B2G	Dryland horticulture, agro-horticulture and intensive agriculture
H	4D5B4B2H	Agro-horticulture, dryland horticulture and fodder & fuel
I	4D5B4B2I	Fodder & fuel, agro-horticulture, dryland horticulture and agro-forestry
J	4D5B4B2J	Agro-horticulture, dryland horticulture, fodder & fuel and intensive agriculture
K	4D5B4B2K	Fodder & fuel, agro-horticulture, dryland horticulture and aforestation
L	4D5B4B2L	Agro-horticulture, aforestation, fodder & fuel and intensive agriculture
M	4D5B4B3M	Aforestation, agro-horticulture, dryland horticulture and fodder & fuel
N	4D5B4B3N	Agro-horticulture, fodder & fuel and intensive agriculture
O	4D5B4B3O	Fodder and field, agro-horticulture and dryland horticulture
P	4D5B4B3P	Agro-horticulture, dryland horticulture, intensive agriculture and fodder & fuel
Q	4D5B4B3Q	Agro-horticulture, dryland horticulture and fodder & fuel
R	4D5B4B3R	Fodder & fuel, dryland horticulture, intensive agriculture and agro-horticulture
S	4D5B4B3S	Agro-horticulture fodder & fuel, aforestation and intensive agriculture
T	4D5B4B3T	Agro-horticulture, intensive agriculture and fodder & fuel
U	4D5B4B3U	Agro-horticulture, agro-forestry and intensive agriculture

Table 6: List of agricultural crops, tree species and grasses recommended for Medak Nala watershed, Sedam taluk, Gulbarga district

Sl. No.	Suggested land use	Crops suggested		Horticulture/tree species/grasses
		Rainfed	Irrigated	
1	Agro-horticulture (in some cases bund plantation of Horticulture crops suggested)	Pigeon pea, Green gram, Black gram, Sorghum etc.	Paddy, Chcikpea, Wheat etc.	Guava, Jatropha, Sapota, Mango etc.
2	Agro-forestry	Green gram, Black gram, chilli etc.	Bengal gram, Sesamum, cotton Groundnut, etc.	Neem, Ber, Tamarind, Teak etc.
3	Dryland-horticulture	---------	Vegetables like Onion, Brinjal, Tomato etc.	Jatropha, Custard Apple, Tamarind, Sapota etc.

Table 6: Continue

Sl. No.	Suggested land use	Crops suggested Rainfed	Irrigated	Horticulture/tree species/grasses
4	Intensive agriculture	Pigeon pea, chilli + cotton, etc.	Black gram + Green gram, Sugarcane, Maize, Sunflower etc.	Guava, Custard Apple, Mango etc.
5	Fodder and fuel	--------	---------	Prosopis juliflora, Subabul, Sesbania etc.
6	Agriculture plantation	--------	Sugarcane, Turmeric etc.	Banana, tamerind
7	Aforestation	--------	-------	Neem, Tamarind, Teak, Ber, Eucalyptus etc.

Table 7: Alternate land use practices suggested for Medak Nala watershed, Sedam taluk, Gulbarga district, Karnataka

Sl.No.	Land use system	Area (ha)	% of Total Geographical Area
1	Afforestation /Silvipasture	343	2.83
2	Agriculture Plantation	10	0.08
3	Agro-Forestry	217	1.79
4	Agro-Horticulture	5,575	45.93
5	Dryland Horticulture	2,725	22.45
6	Fodder & Fuel	2,290	18.86
7	Intensive Agriculture	432	3.56
8	Settlement	180	1.48
9	Stream	205	1.69
10	Tank – Dry	78	0.64
11	Tank – Water spread	84	0.69
Total		12,139.00	100

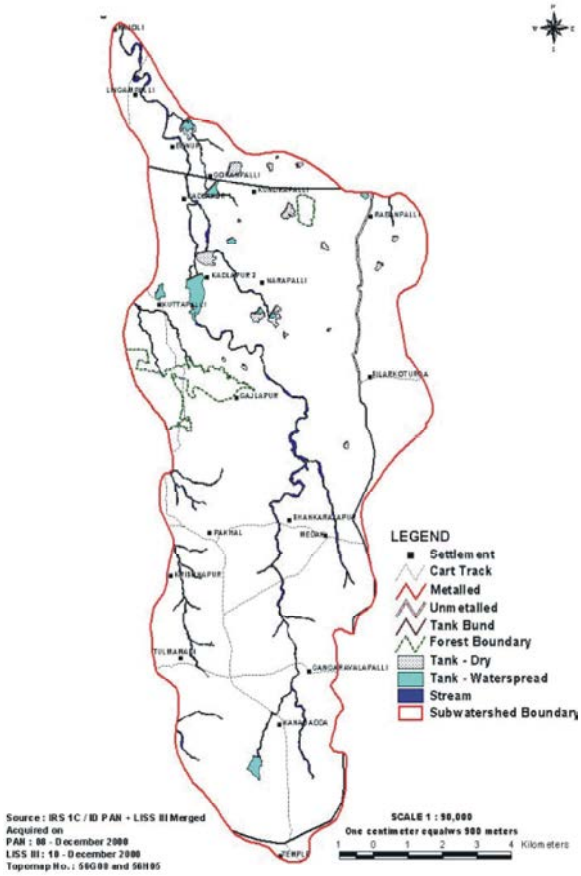

Fig. 3: Base map of Medak Nala watershed watershed

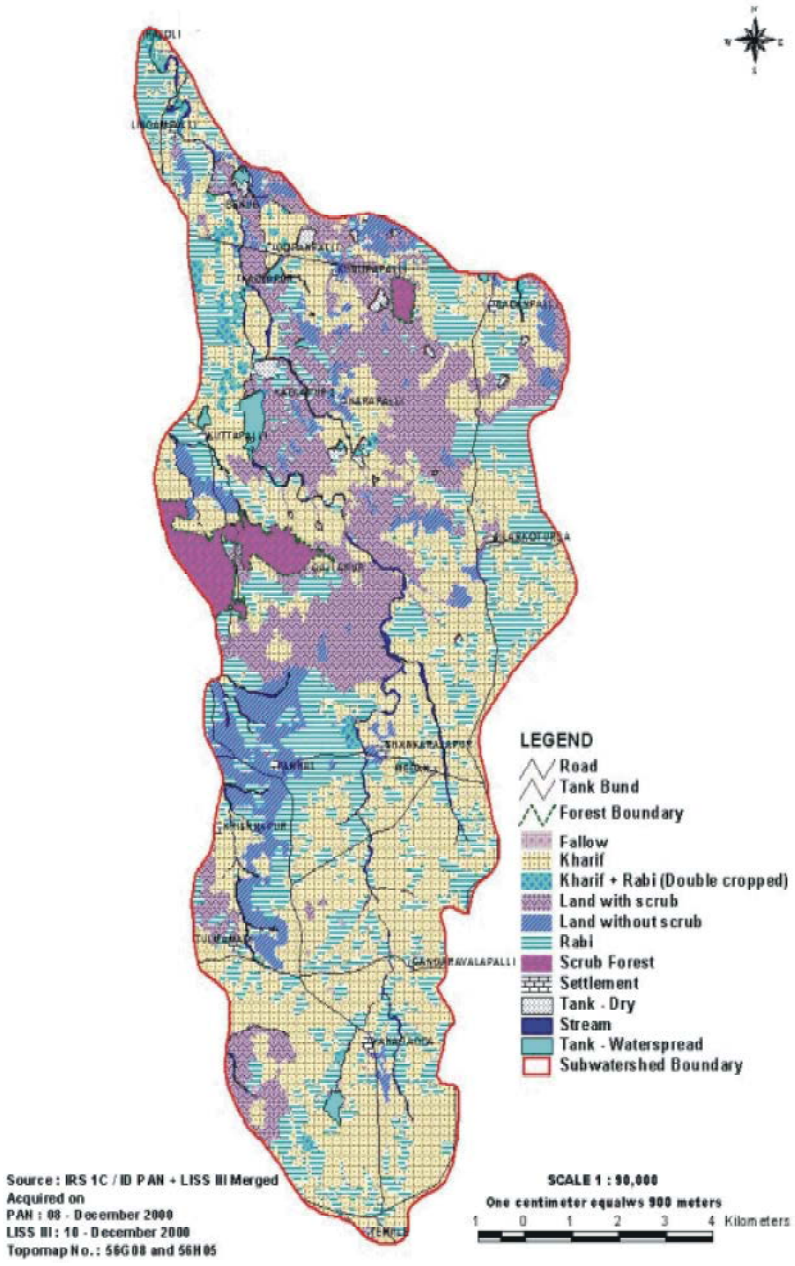

Fig. 4: Land use / land cover map of

integrated along with collateral data such as meteorological conditions, demand and supply of commodities, socio-economic and demographic data to generate composite resource intensity units. These units have information on soil type, its constraints, ground water potential and topography [32]. Each of these resource units were compared with the present land use. In such areas where the resources were not utilized up to its potential, an alternate land use practice was suggested by giving due weightage to the local needs of the people. Similar studies have been reported [28-30]. Wherever the existing land use was economically viable the same practice was recommended with appropriate management practices. Similar studies were made in Lingasur taluk of Raichur district in Karnataka [31].

An area of about 217 ha (1.79% out of total geographical area) was suggested for Agro-forestry. This system is suggested in the vast stretches of scrub lands

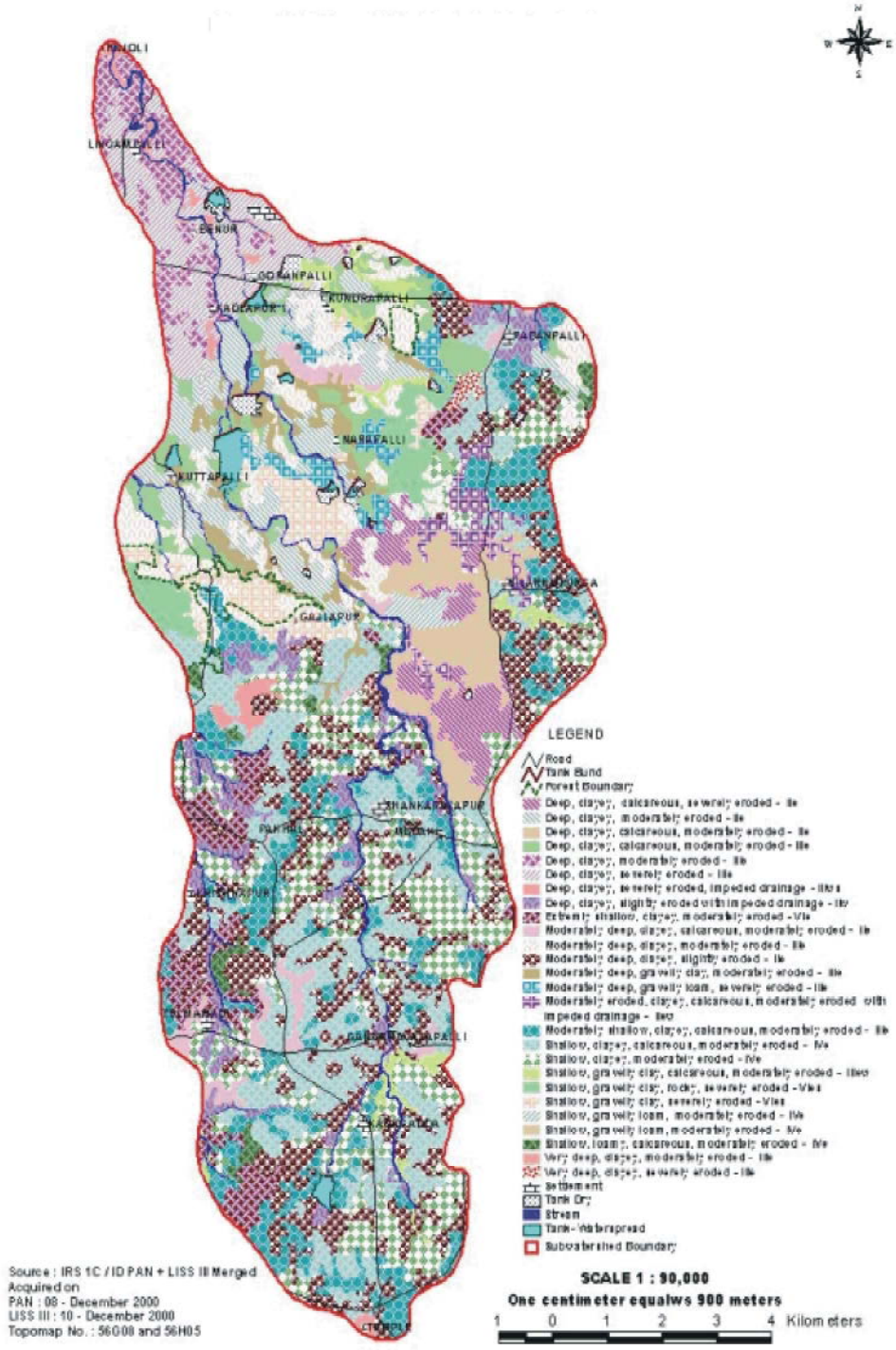

Fig. 5: Soil map of Medak Nala watershed

and also on single cropped area, with either soil suitable for agriculture or not suitable for agriculture on slopes up to 5 per cent with shallow to moderately deep sandy loam to sandy clay loam, soils having poor to moderate ground water potential, thus utilizing the available resources in obtaining additional returns instead of cultivating a single crop. It also helps in creating additional employment, checking soil erosion, improves soil fertility and provides necessary biomass to meet the requirement of fodder and fuel wood as the watershed region was deficit in fodder

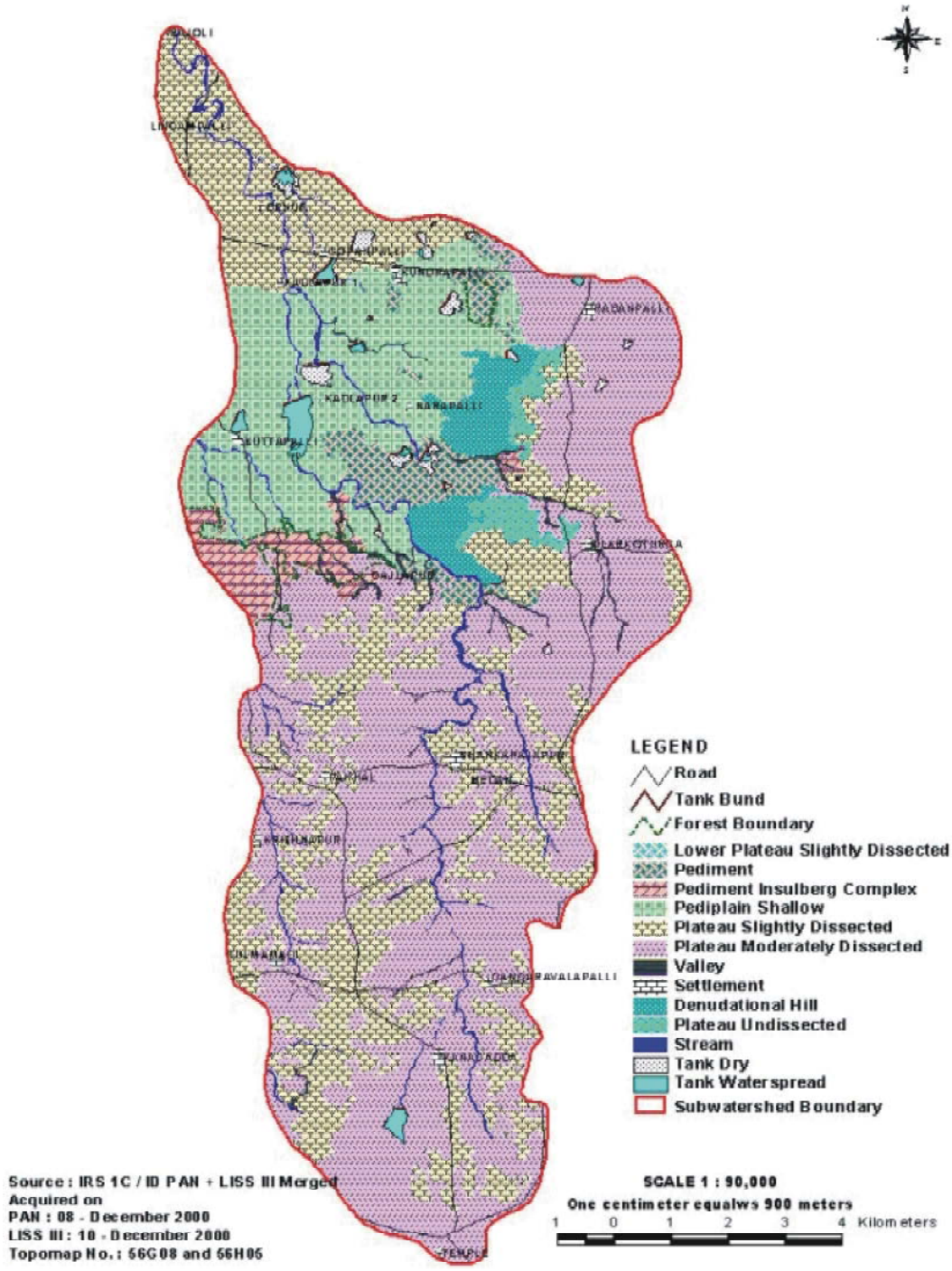

Fig. 6: Hydro-geomorphology map of Medak Nala watershed

and fuel wood supply. Depending on the climatic and edaphic suitability of the species as well as the local need, tree species can be selected. Some of the tree species like glyricidia, tamarind, *Acacia nilotica*, *Neem sps*. *Ficus sps.* etc. have also been suggested. The fruit trees like custard apple, tamarind, ber, mango, guava, sapota and teak plantations with pulses like cluster bean, horse gram, etc. are suggested for Agro-horticultural system, which

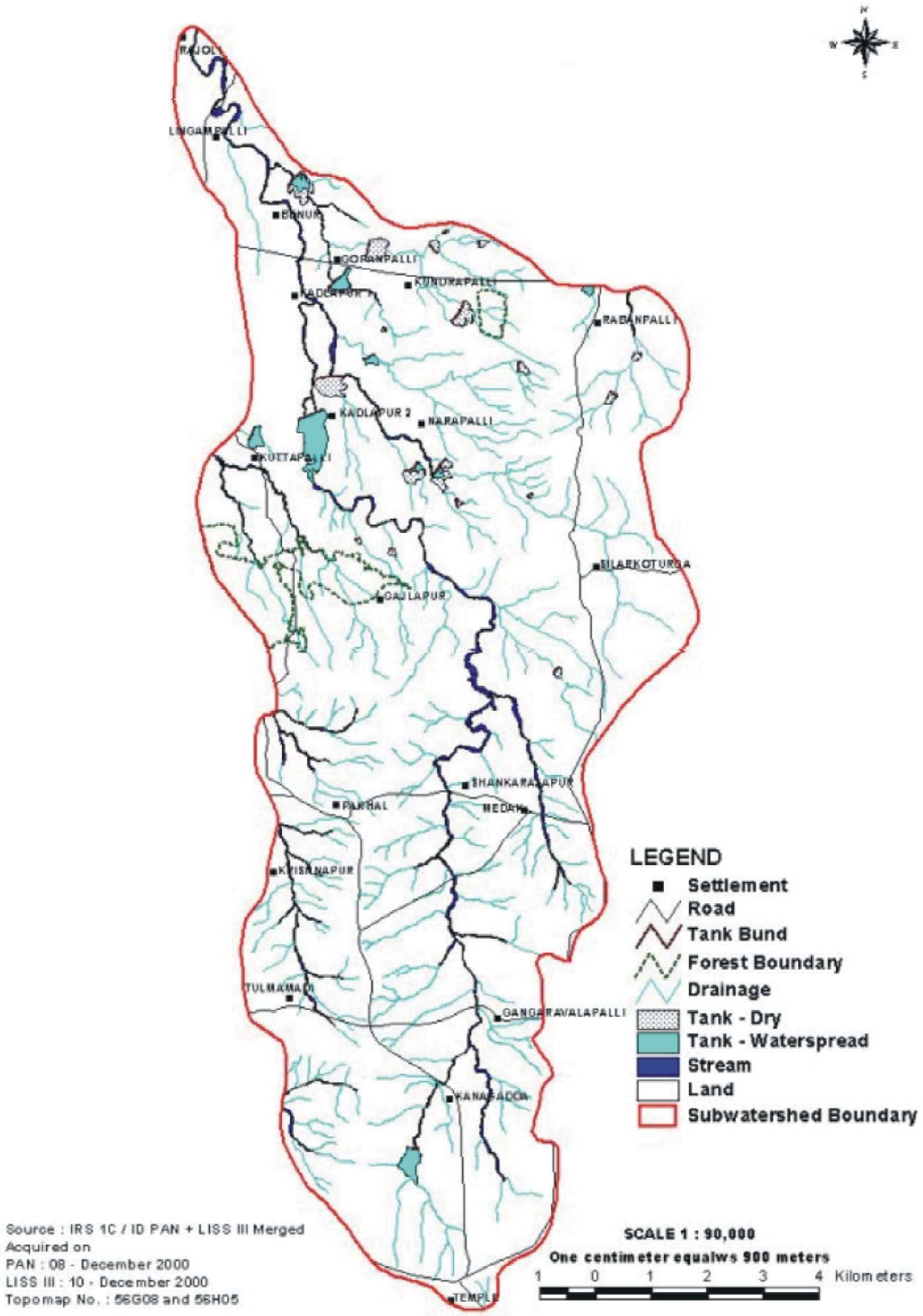

Fig. 7: Drainage map of Medak Nala watershed

accounts for 5,575 ha (45.93% of total geographical area). In order to mitigate the hardship caused due to uneven rainfall, horticultural crops like drumstick, nelli, nerale etc. are also suggested in dry land areas where shallow to deep soils exist. Growing of horticultural crops along with agricultural crops increases economic returns. Shallow to

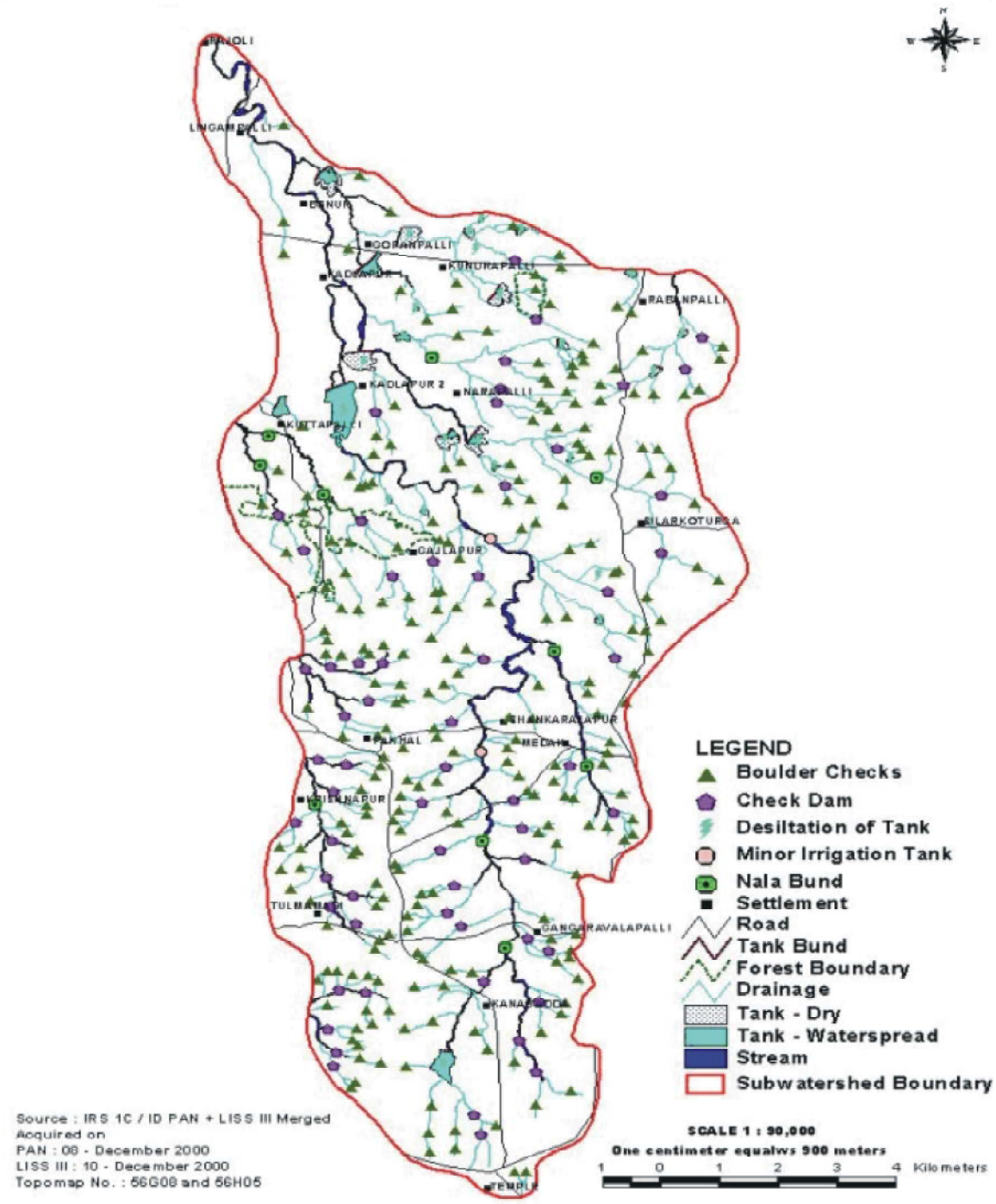

Fig. 8: Water Resources Action plan map of Medak Nala watershed Nala

deep, gravelly sandy loam to clay loam soils that are nearly level to gently sloping, with moderate to good ground water potential, are suggested for taking up agro-horticulture. Dryland horticulture covers an area of about 2725 ha (22.45%) of total geographical area. The horticulture crops like tamarind, ber, jack, fig, custard apple etc. were suggested in shallow to moderately deep, sandy loam to sandy clay loam soils on gently sloping to moderately sloping lands with moderate to good ground water potential. This system provides incremental returns from the *kharif (autumn)* and fallow lands thus generating more income from the rainfed areas (Table 6).

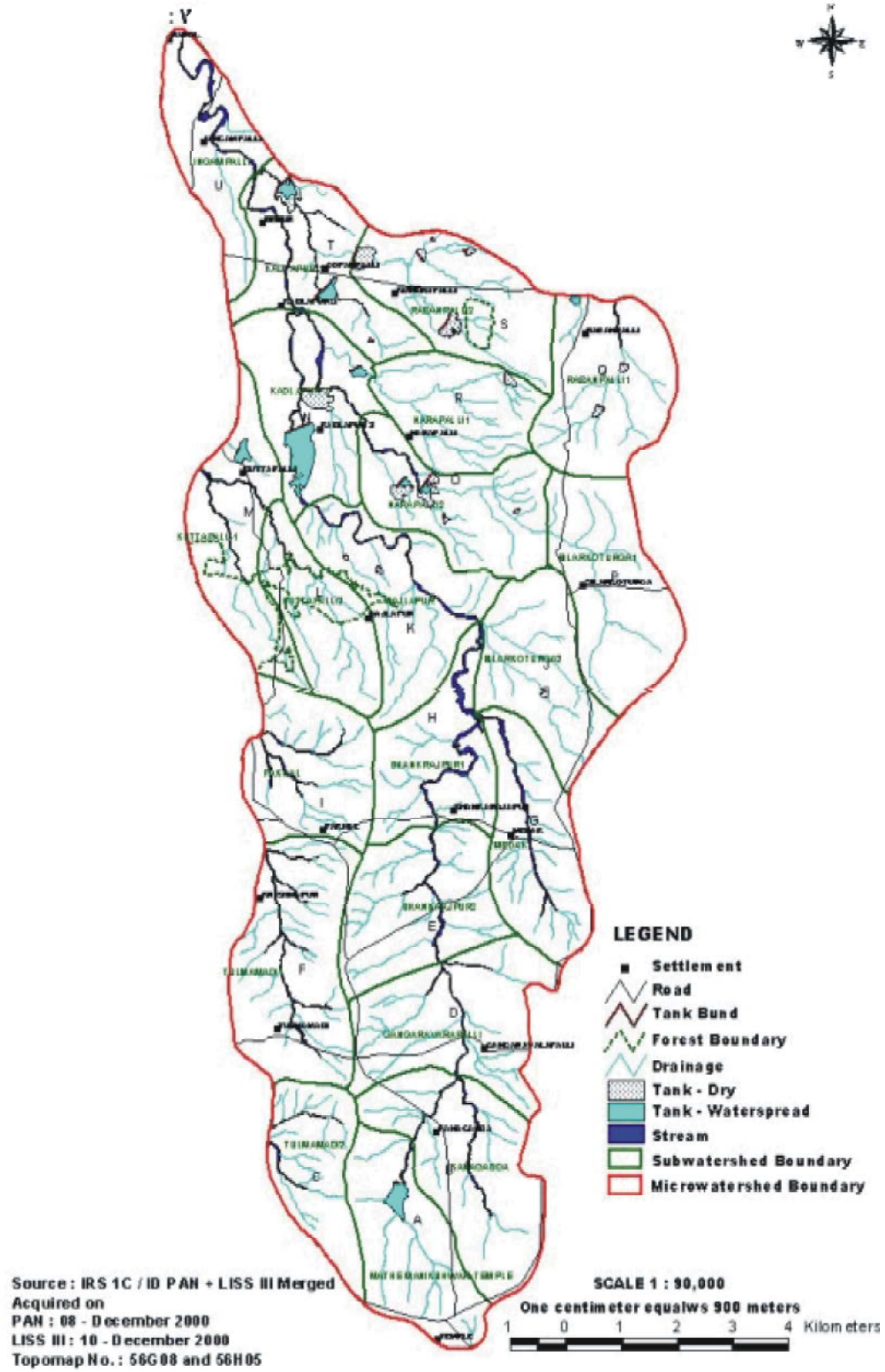

Fig. 9: Micro-watershed delineation map of Medak Nala watershed

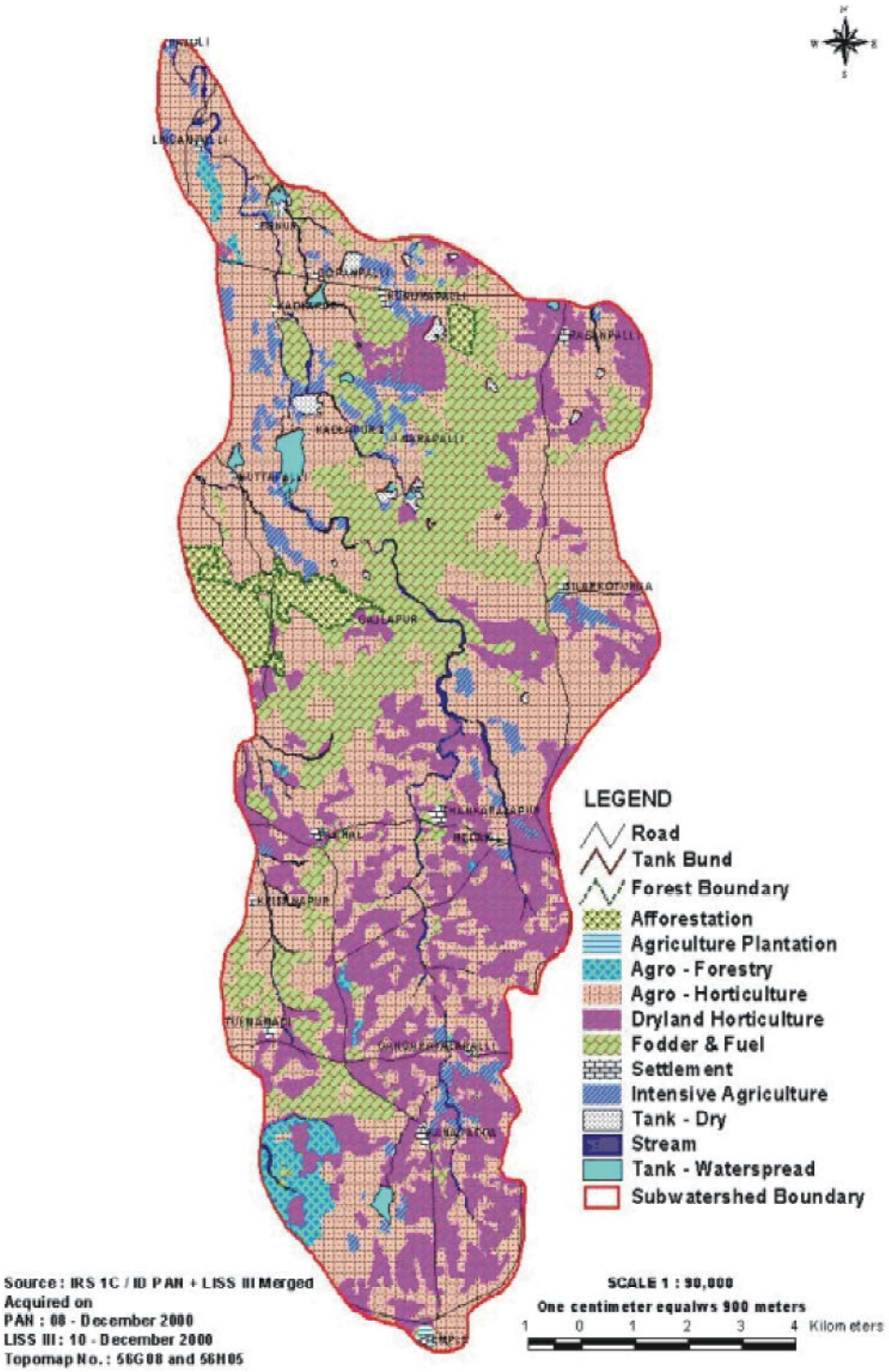

Fig. 10: Agricultural Resources Action plan map of Medak Nala watershed

In the hilly area of moderate to steep slope with moderate deep, clayey soils agricultural plantation was advocated. Growing of fruit, fuel, timber, fodder bearing plantations (Bellary jali, subabul, sesbania, eucalyptus, etc.) in non-notified areas is suggested. Agricultural plantation accounts for 10 ha (0.08% of total geographical

area). This system provides additional income with fiber, fuel, fodder and timber from the same piece of land thus attaining self-sufficiency in fodder and fuel requirement. The fodder and fuelwood plantation was recommended in shallow, clayey, moderately eroded, deep clayey, calcareous, severely eroded soils with the present land use being scrub and single crop land. It was noticed from the demand and supply analysis that fodder requirement was more when compared to the actual availability. The fodder and fuel wood species like Glyricidia, Jatropha, *Ficus religiosa*, Subabul, Neem, *Albizia lebbeck* etc. are suggested depending on suitability. The area under this class occupies 2290 ha (18.86% of total geographical area). The production systems including *Acacia albida, Acacia farnasiana, Albizzia lebbek, Leucaena leucocephala, Pongamia pinnata, Prosopis juliflora, etc.* were suggested in such a way that the demand for fodder and fuel is met from both arable and non-arable lands.

Afforestation is suggested on scrub forest areas where there is negligible vegetation with nearly level to moderate slope so that the fuel-wood and forest resources can be utilized for economic gains. In all about 343 ha (2.83% of total geographical area) has been recommended for afforestation (Table 7). The tree species like *Cassia siamea, Azardirachta indica, Eucalyptus camaldulensis* etc. have also been recommended.

Intensive agriculture mostly confined to valleys, alluvial tracts and other areas where the ground water and nutrient status are high. In this class intercropping, strip cropping, relay cropping and crop rotation were followed. This class was suggested in 432 ha (3.56% of total geographical area). The areas in single crop system with moderately deep to deep soil on nearly level to very gently slope and good to moderately good groundwater potential or accessible surface water resources or both can be put into intensive cropping system. By following this system, there will be an improvement in economic situation as a result of change from existing single crop to intensive cropping system. This is due to overcoming the water resource limitation by exploiting either the available good ground water potential or the proximal surface water resources or both. Hence cropping systems such as inter cropping, strip cropping and relay cropping were suggested. Inter cropping consists of growing one minor crop, generally leguminous with one major crop usually cereal. Some of the intercropping systems suggested are sorghum + redgram (2:1 or 4:2), sunflower + redgram (2:1), groundnut + redgram (5:1). Strip cropping consists of growing few rows of erosion resistant crops and erosion permitting crops in alternate strips on contours or across the slope. Crop mixtures involved are legumes, cereals, grasses and short duration vegetable crops. Relay cropping refers to growing different mono-crops sequentially spreading over to 2-3 seasons in a year. Before the harvest of the cereal crop (maize), a pulse crop (chick pea) could be sown by broadcasting to thrive on the residual moisture.

CONCLUSION

It is apparent from the foregoing that there is a tremendous scope for frontier technologies in developing a database of agricultural resources and decision support systems at the farm (<1 ha) level. The study concludes that remote sensing and GIS technologies can be used for scientific planning and management of natural resources. The generation of alternative land use / land cover practices for natural resources management involves careful study of thematic maps both individually and integrated basis as well. Keeping in view the conservation and improvement of the available arable and non-arable land, action plans are generated in an integrated way for different land use systems based on systematic assessment of physical capability, economic viability and technical feasibility.

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