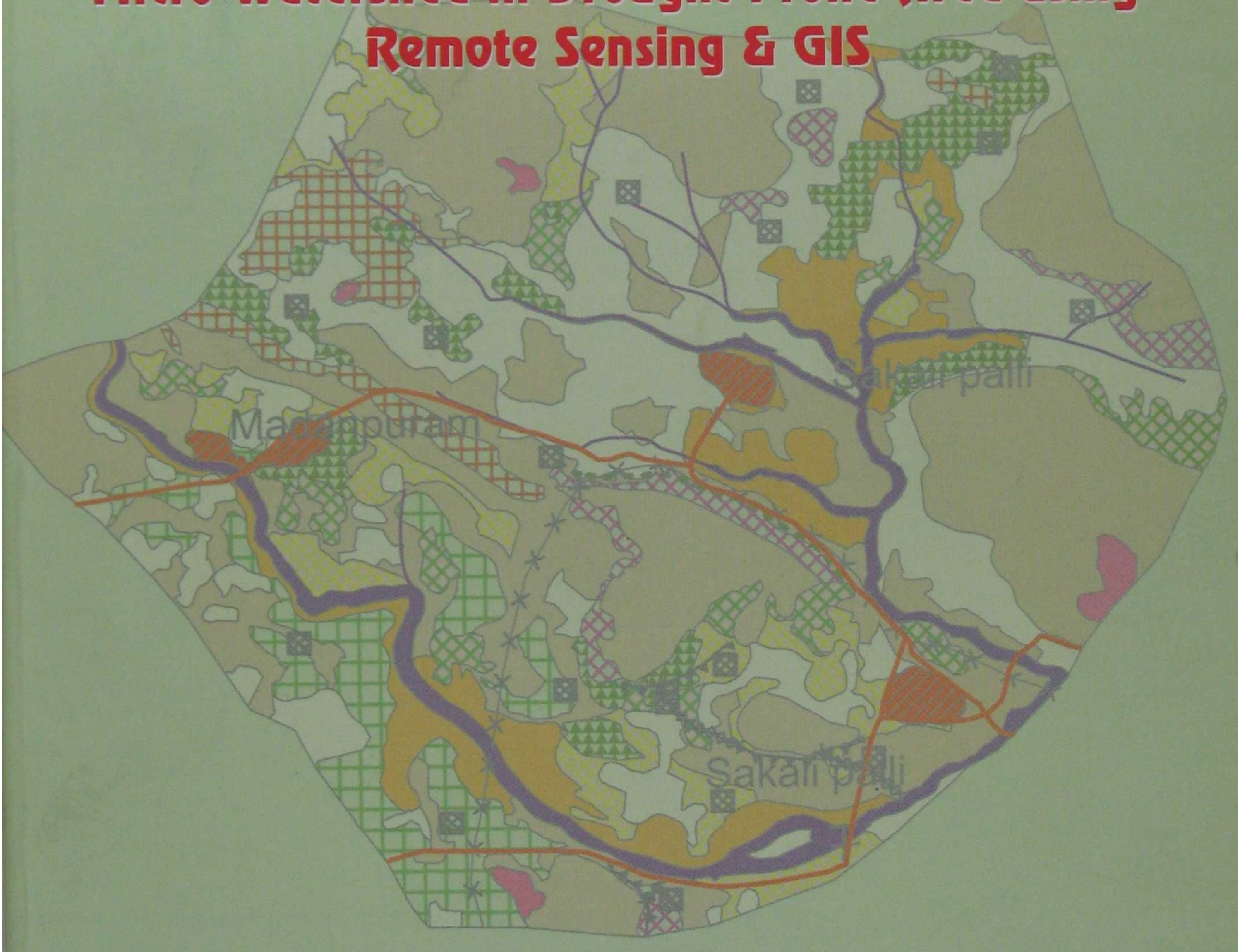
Prioritization, Planning & Development of a Micro-watershed in Drought Prone Area using Remote Sensing & GIS



CRIDA:
P.K. Mishra, M. Osman, V. Ramesh

NRSA:
B.R.M. Rao, S.S. Thamappa, S.K. Subramaniam

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Foreword

Water as driver of the ecosystem and watersheds as hub of all activities have assumed a great significance in rural India. Watershed activities are pre-cursor to efficient management of all natural resources required for sustainable agriculture in drylands. A second green revolution in agriculture is possible only through efficient management of natural resources in drylands which contribute 44% of total food grains and 90% of coarse cereals essential for well-being of human and livestock. Coarse cereals are not only a source of rich nutrition but also provide quality fodder for livestock. It gives me an immense pleasure to mention that this project has focused on identifying areas that needed treatment on priority having large area under coarse cereals, mainly sorghum. The efforts made jointly by CRIDA and NRSA in perfecting the methodology and in making use of modern tools like Remote Sensing and GIS is commendable. The watershed action plan was prepared and implemented on scientific principles in a participatory mode. Prevailing drought situation all through the project period didn't reduce the spirit of farmers and project implementing officials. This reflects good faith of the farming community in watershed approach and hope that more benefits will be reaped in years with good rainfall.

The implementation of this programme in the rainfed agro-ecosystem under NATP has further improved the capability of scientists and staff as well. Those who were involved in this programme are now fully equipped to meet the growing expectations of farmers, State and Central Government too. Demonstration of low cost appropriate technologies for enhancing productivity like improved seed; moisture and plant nutrition would go a long way in meeting the challenges of burgeoning population. The livelihoods approach of watershed management has now given a further impetus to not only those who own land but also to landless and artisans who are an integral part of the rural community. These efforts to achieve sustainable livelihoods in rural areas through efficient management of natural resource on watershed mode would be further strengthened and hope that, learnings from this project will be made use by one and all interested in dryland agriculture. I congratulate Dr. P.K. Mishra and his team for bringing out this useful publication on "Prioritization, Planning & Development of a Micro-Watershed in Drought Prone Area of Nalgonda District in Andhra Pradesh" as an output of the NATP (RNPS-2) project of CRIDA centre.

(Y. S. Ramakrishna)
Director, CRIDA
Hyderabad

Hyderabad
29th December, 2004

Acknowledgements

The authors are highly grateful to Dr. Y.S. Ramakrishna, Director, CRIDA and Director of Agro-Ecosystem (Rainfed) of NATP and Dr. R.R. Navalgund, Director, NRSA, Dr. P.S. Roy, DD (RS&GIS), NRSA for constant guidance, which led to the successful accomplishment of this endeavour. We wish to place our deep appreciation to Dr. B.V. Venkateswarlu, PPSS (NATP) and his associates for active administrative support. We are highly indebted to Mrs. Sujatha, Dr. Ravisankar, Mr. M.A. Fyzee, Mr. Sriramkoti, Mr. Dinesh Kar for the technical support at different stages during the course of investigation. We are grateful to all CRIDA staff particularly Mr. J.B. Ramappa, V. Sambasiva Rao, B. Narsimlu and the project staff Mr. M. Sridhar, Mr. S. Raghava Sarma and Miss Kouser Afshan for their devotion and hard work. Last, but not the least we extend our deep appreciation to all the farmers of the study area for their faith in us and support inspite of drought situation throughout the project period.

Project Team

Contents

1.0 Introduction

In India dry lands contribute to 44% of total food grains and 75% of pulses and oil seeds. About 90%of coarse cereals are produced in dry land. Dry land agriculture is facing multiple problems in terms of climate, soil/land resources and socio-economic constraints. The rainfall is scanty and crops suffer due to low soil moisture availability and nutrient deficiencies. The farmers are mostly resource poor, debt ridden and locked in poverty line. Though, many technologists have been developed to improve the productivity of drylands, a holistic approach on watershed domain is lacking. The sustainable agriculture calls for development of land and water resources without deterioration of ecosystem and sustained productivity. The 'watershed approach' represents the principal vehicle for transfer of rain fed agriculture technology. A watershed (or catchment) is a geographic area that drains to a common point, makes it an ideal planning unit for conservation of soil and water. It is a holistic approach for the development of agriculture and allied activities. In NATP crop production system based approach is the special feature that distinguishes from other watershed development programmes. The key attributes of watershed management are conservation of rain water and optimization of soil and water resources in a sustainable and cost effective mode. It aims to optimize moisture retention and reduce soil erosion, thus maximizing productivity and minimizing land degradation. Currently a large number of projects for productivity enhancement are being implemented based on the watershed approach. A second green revolution in agriculture is possible only through efficient management of natural resources in drylands. The project has focussed on identifying areas that needed treatment on priority having large area under coarse cereal, mainly kharif sorghum in dry land areas of Andhra Pradesh.

Remote sensing has provided a new impetus for the earth resources and environmental scientist to study natural resources in spatial and temporal domain. India began development of an indigenous IRS (Indian Remote Sensing Satellite) program to support the national economy in the areas of Agriculture, Water resources, Forestry and Ecology, Geology, Watersheds, Marine fisheries and Coastal management. Remote sensing applications in the country, now cover diverse fields such as soils, land degradation, crop acreage and yield estimation, drought assessment and warning ,flood control and damage assessment, land use/land cover information, management of watersheds and command areas, waste land management, water resources management, reduction of snow-melt run-off, fisheries development ,mineral prospecting and forestry resources. With the advent of high resolution satellite data new aplications in the areas of urban sprawl, micro-watershed development, infrastructure planning and other large scale applications have been initiated.

Keeping the above points in view, a project has been taken up with an idea of developing regional level watershed development plans using the Remote Sensing and GIS techniques, development of methodology to identify the critical areas for prioritized land treatment, selection of a micro watershed from the critical areas for detailed inventory at 1:12,500 scale and development of action plans and their implementation in a participatory mode.

2.0. Description of the Study Area

2.1 Location and extent

Sasileruvagu watershed falls in Chintapalli mandal of Nalgonda district in Andhra Pradesh (Fig. 3.1). Geographical area of the watershed is 1.31 lakh hectares. The watershed lies in between $16^0 38'$ 37'' and 16^0 59' 20" North latitudes and 78^0 40' 41" and 79^0 18' 43" East longitudes. It is covered by survey of India topographical maps 56L/10, 56L/14, 56P/2, 56P/5, and 56P of scale 1:50000. Sasileruvagu is a tributary to Krishna River.

2.2 Physiography

The major lithology of the area consists of weathered granites. Physiography of the area consist of residual hills, isolated hills/hillocks (inselburgs), dykes, pediments, pediments inselburg complexes, undulating pediplains and valleys. A major part of watershed is under undulating pediplains developed over weathered granite gneisses. The slope of study area ranges from 1-8%.The average elevation ranges between 240 and 500 meters above mean sea level (MSL).

2.3 Drainage

Sasileruvagu is the main stream that drains the study area from Nalgonda and Ranga Reddy districts. Fig 3.5 shows the dendritic drainage pattern observed in the study area.

2.4 Climate

The climate of the project area falls under the typical subtropical monsoon type. Most of the rainfall is received during the months of June to September. Minimum and maximum rainfall received in the study area is 331mm and 912mm, respectively. The study area is generally dry and during the summer months temperature rises up to 45^0C

2.5 Natural vegetation

The study area is devoid of forests. The natural vegetation belongs to tropical dry deciduous, thorny forest type, bushes, scrubs, etc. The common tree species observed are babul *(Acacia-sps)*, Neem,*(Azadirachta indica)*,Tamarind*(Tamarindus indica)*,palm and grasses.

2.6 Agriculture and socio economic conditions

Cereals like, sorghum, bajra, and pulses like, redgram, green gram and oil seeds are predominantly grown in kharif season. The land is monocropped, dry, no irrigation facilities are available. The soils are low in fertility status. Economically the farmers are very poor.

3.0 Development of Methodology for Identification of Critical Areas in the Watershed

In the present study a methodology was developed, which involves identification of critical areas for prioritized land treatment in the watersheds on regional scale under different crop production systems. The flow chart of activities for the identification of critical areas is presented in fig. 3.2 for prioritization of the developmental work.

The Indian Remote Sensing Satellite I-C- Linear Imaging Self Scanning Sensor(IRS LISS-III) FCC prints of April 4th, 2000 for Sasileruvagu watershed, and IRS-IC-LISS-III +PAN merged FCC prints of 13th October,2000 for Sakaliseripalli microwatershed was used. Besides the satellite data, Survey of India topomaps, published reports, climatic data, and watershed atlas prepared by AIS &LUS were also used.

Table 3.1 Satellite data used

SENSOR	PATH/ROW	DATE OF ACQUISION	TYPEOF DATA	SCALE
IRS-IC-LISS-III	100-61	04-04-2000	DIGITAL, and FCC, BANDS 2, 3, 4	1:50,000
RS-IC-LISS-III	100-16	03-10-2000	DIGITAL ,and FCC BANDS 2, 3, 4	1;50,000
RS-IC PAN		05-03-2000	DIGITAL,and B5	1:25,000
			(PAN MERGED DATA)	.1.12,500

Initially, the soil map of the watershed was prepared at 1:50,000 scale using latest satellite data from IRS – IC / ID satellites following visual interpretation approach with soil profile study, soil analytical data and classification of soils as per soil taxonomy. Digital database for the soil map was prepared using Arc INFO GIS package and attribute data were incorporated for each soil-mapping unit. The parameters considered for identification of critical areas using National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) manual are soil depth, soil texture, internal drainage, slope, erosion and soil reaction (Tables 3.1 to 3.6). The soil polygons were re-classified based on the above parameters and individual thematic layers were generated. Area statistics were generated for the watershed parameter-wise to identify the critical parameter in the watershed from crop productivity point of view. A composite layer was generated from the individual thematic layers and the critical areas were mapped based on the limitations of the above mentioned soil parameters. Rules were framed to group polygons with severe limitations under each parameter as high priority zone and polygon with no limitations under least priority zone. Polygons with moderate limitations were grouped under medium priority zone. This knowledge base was applied on to the composite layer and composite polygons were reclassified and map showing priority zones were developed. The various steps involves in the methodology for delineation of critical area for prioritization and development is summarized in the flow chart (Fig 3.2).

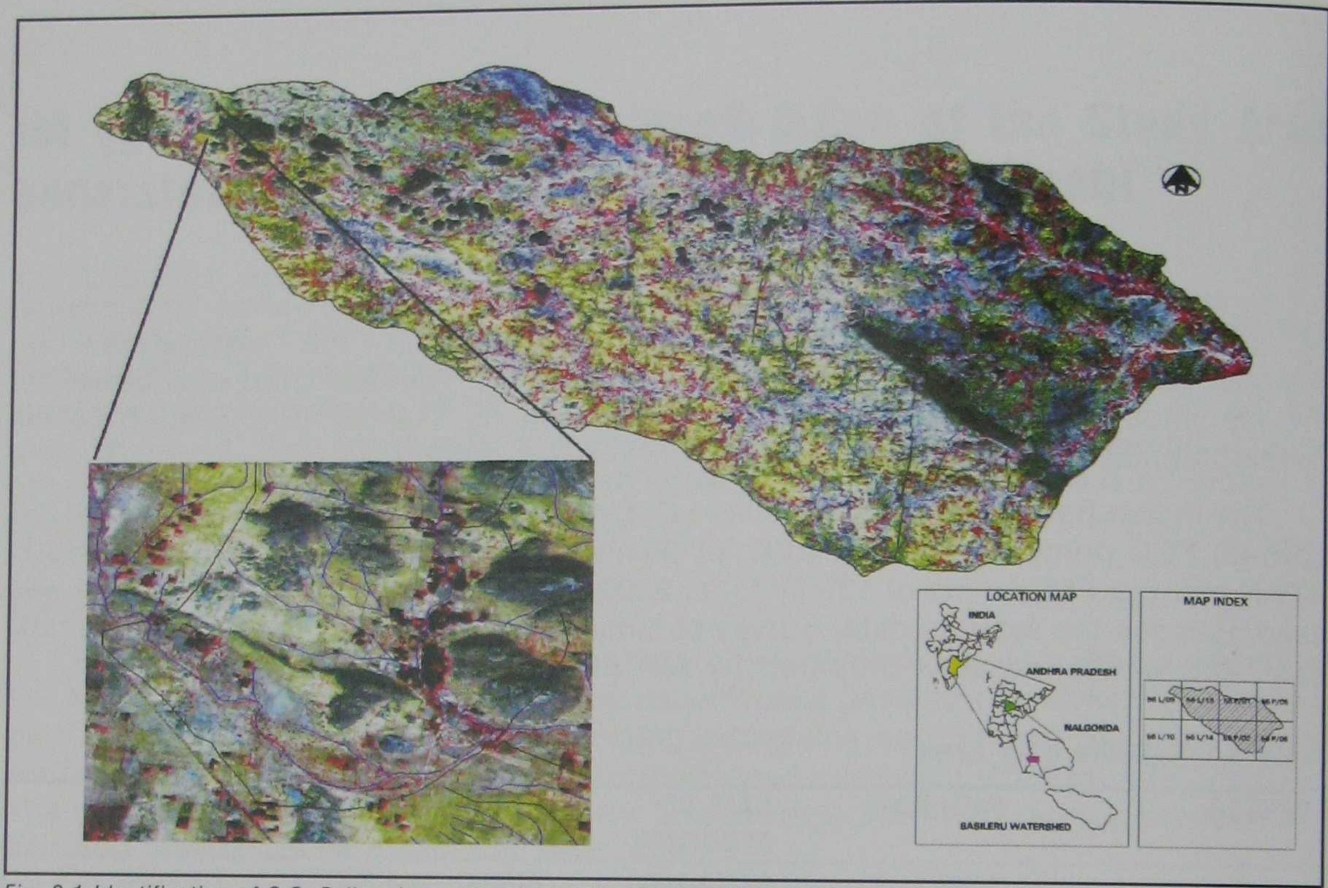


Fig. 3.1 Identification of S.S. Pally micro-watershed under Sasileru Vagu basin in Nalgonda district of A.P. for intervention

The parameters considered for indentification of critical areas are presented in tables 3.1 to 3.6

Natural resource inventory of the Sasileru Vagu watershed was carried out and different maps, namely soil map drainge map, hydrogeomorphology map, land & water resource maps, priority maps and critical map were generated at 1:50,000 scale using satellite data, which spread over an area of 1.3 lakh/ha in Nalgonda and Ranga Reddy districts (Figs 3.4 to 3.10). The soil map of the watershed was prepared and mapped at the level of soil series association. Derivative maps from the soil maps were prepared and critical areas were identified in the watershed. The shallow soils occupy an area of 11221 hectares (8.56 % of the watershed), soil slope problem was noticed to an extent of 4.08 % which occupies an area of 5346 ha. Severely eroded soils occupy 5346 ha and soils with moderate erosion occupy 16326 ha (12.46%).

A representative micro watershed of an area of 765 ha in S.S. Pally was identified from the high priority zone for preparing natural resource inventory at 1:12,500 scale using high resolution satellite data. Critical areas were identified in the micro watershed using the above-mentioned methodology and a action plan was suggested for kharif sorghum production system. The thematic maps like soil map, land use land cover and land and water resources development plan map (Figs. 3.11 to 3.13) were generated for the S.S. Pally micro watershed.

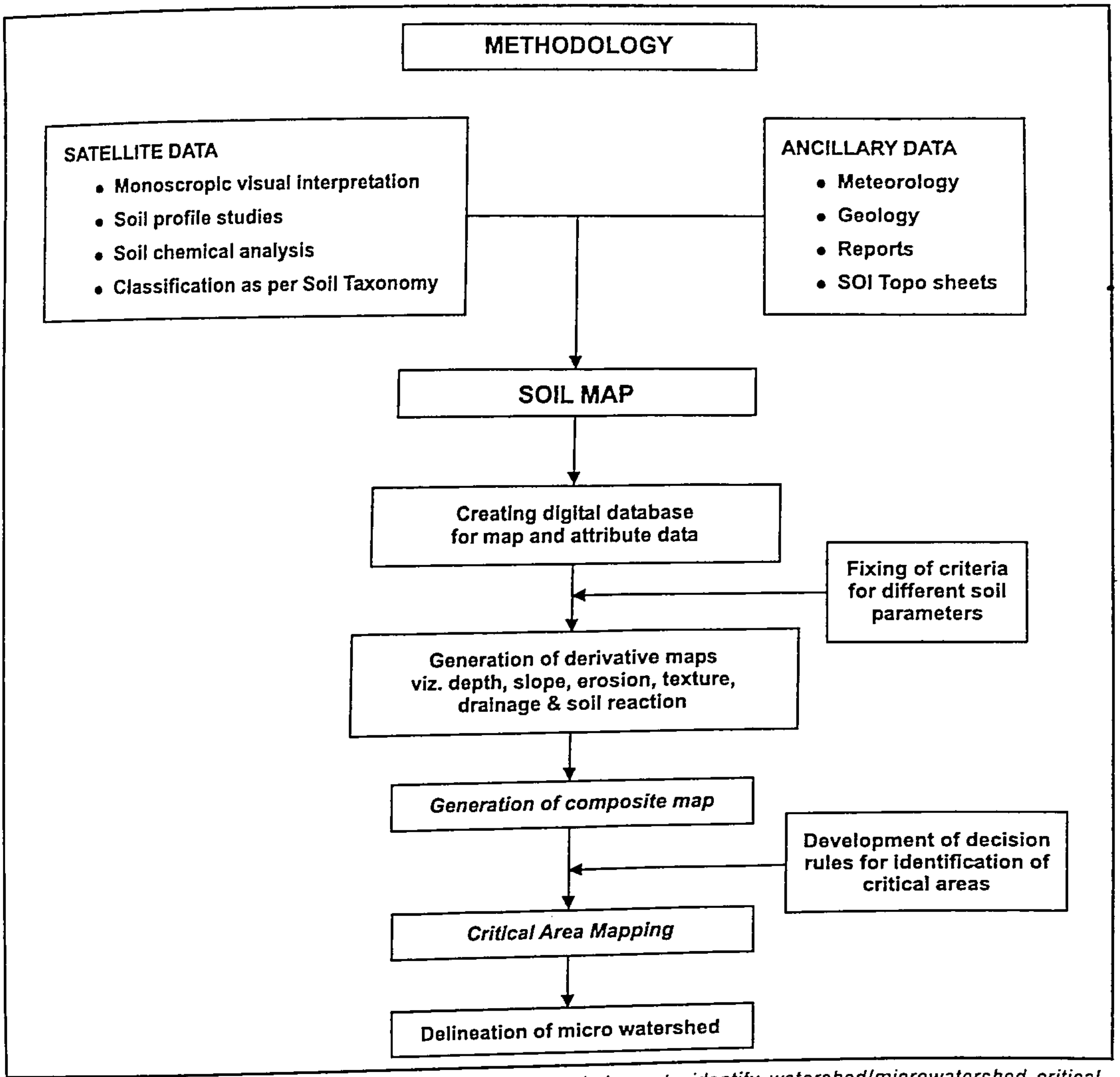


Fig. 3.2 Operational methodology, based on remote sensing techniques to identify watershed/microwatershed critical areas for prioritization & development.

Table 3.1 Soil depth classes

Symbol	Depth (cm)	Series
1	<10	Extremely shallow
2	10-25	Very shallow
3	25-50	Shallow
4	50-75	Moderately shallow
5	75-100	Mod. Deep
6	100-150	Deep
7	150+	Very deep

Table 3.2 Slope classes

Symbol	Class	% Slope
1	Level to nearly level	0-1
2	Very gently sloping	1-3
3	Gently sloping	3-8
4	Moderately sloping	8-15
5	Moderately steeply sloping	15-30
6	Steeply sloping	30-50
7	Very steeply sloping	>50

Table 3.3 Texture classes

Symbol	Surface Texture	Texural Class	Clay distribution (%)
1	Very fine	clay	60 or more
2	Fine	Sandy clay; Silty clay	40-60
3	Moderately fine	Sandy clay loam, Silty clay loam Clay loam	35-40
4	Medium fine	Silt loam, Silt	28-35
5	Medium	Very fine sandy loam, loam	18-27
6	Medium coarse	Sandy loam, Fine sandy loam	10-18
7	Coarse	Loamy sand	10-15%
8	Very coarse	Sand	< 10%

Source : Brady and Weil, 1999

Table 3.4 Erosion classes

Symbol	Class		
1	Nil to slight	e1	Sheet or rill erosion
2	Moderate	e2	Deep or rills
3	Severe	e3	Deep gullies
4	Very severe	e4	Ravenous land

Table 3.5 Drainage classes

Symbol	Description
1	Extremely poor
2	Very poor
3	Poor
4	Imperfect
5	Mod. well drained
6	Well drained
7	Some what excessive
8	Excessively drained

Table 3.6. Soil reaction classes

Symbol	Description	pH range
1	Normal	6.5 –7.5
2	Slightly alkaline	7.5 –8.5
3	Moderately alkaline	8.5 –9.0
4	Strongly alkaline	9.0 –9.8
5	Slightly acidic	5.5 –6.5
6	Mod. acidic	5.0 –5.5
7	Strongly acidic	4.5 –5.0

Sasileru Vagu watershed encompasses 15 mandal as presented in table 3.7. The villages identified as critical areas for taking of watershed development programme on priority is present in table 3.8.

Table 3.7 Mandals under the Sasileru vagu watershed

S.No	Station name
Nalgonda	1. Anumula, 2. Chintapalli, 3. Deverakonda, 4. Gurrampadu, 5. Marriguda, 6. Nampally, 7. Peddavoora, 8. Pochampally, 9. Thungaturthy, 10. Tirumalagiri, 11. Turkapalli, 12 P. A. Palli
Ranga Reddy	1. Yacharam, 2. Ibrahimpatnam, 3. Manchal

Table 3.8 Prioritized villages (under Nalgonda District) for development of watersheds

1	Kurmapalli	13	Vattipalli
2	Badvangudem	14	Yearagandlapalli
3	Takkallapalli	15	Vinjamur
4	Tirugandla pally	16	Paunampalli
5	Tamadpalli	17	Gollapalli
6	Madgulmallepalli	18	Sakaliseri Pally
7	Mallepalli	19	Madanapuram
8	Krishtarmpalli	20	Venkateshnagar
9	Narsimhpuram	21	Tugapati Gauraram
10	Ramareddipalli	22	Krishnapally
11	Thanedarpalli	23	Godkondla
12	Bhimnapalli	24	Polepalli

Considering the low rainfall, high standard deviation and proximity to Ranga Reddy and Mahaboobnagar districts and for having a better demonstration value, 100 ha in Sakaliseri Pally village in Nalgonda district was selected for development. This village is located at the confluence of Nalgonda, Ranga Reddy and Mahaboobnagar districts.

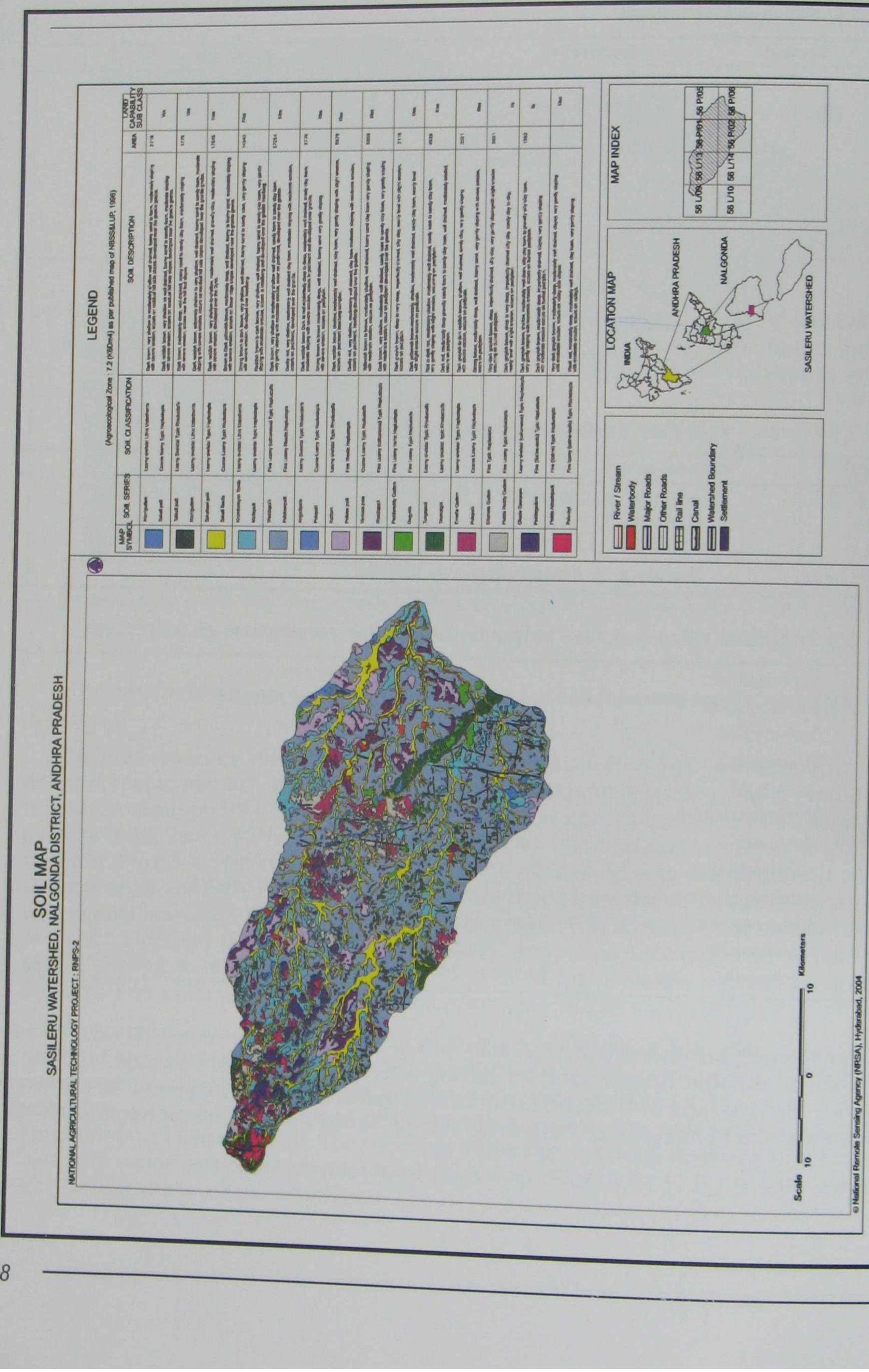


Fig. 3.4 : Soil map

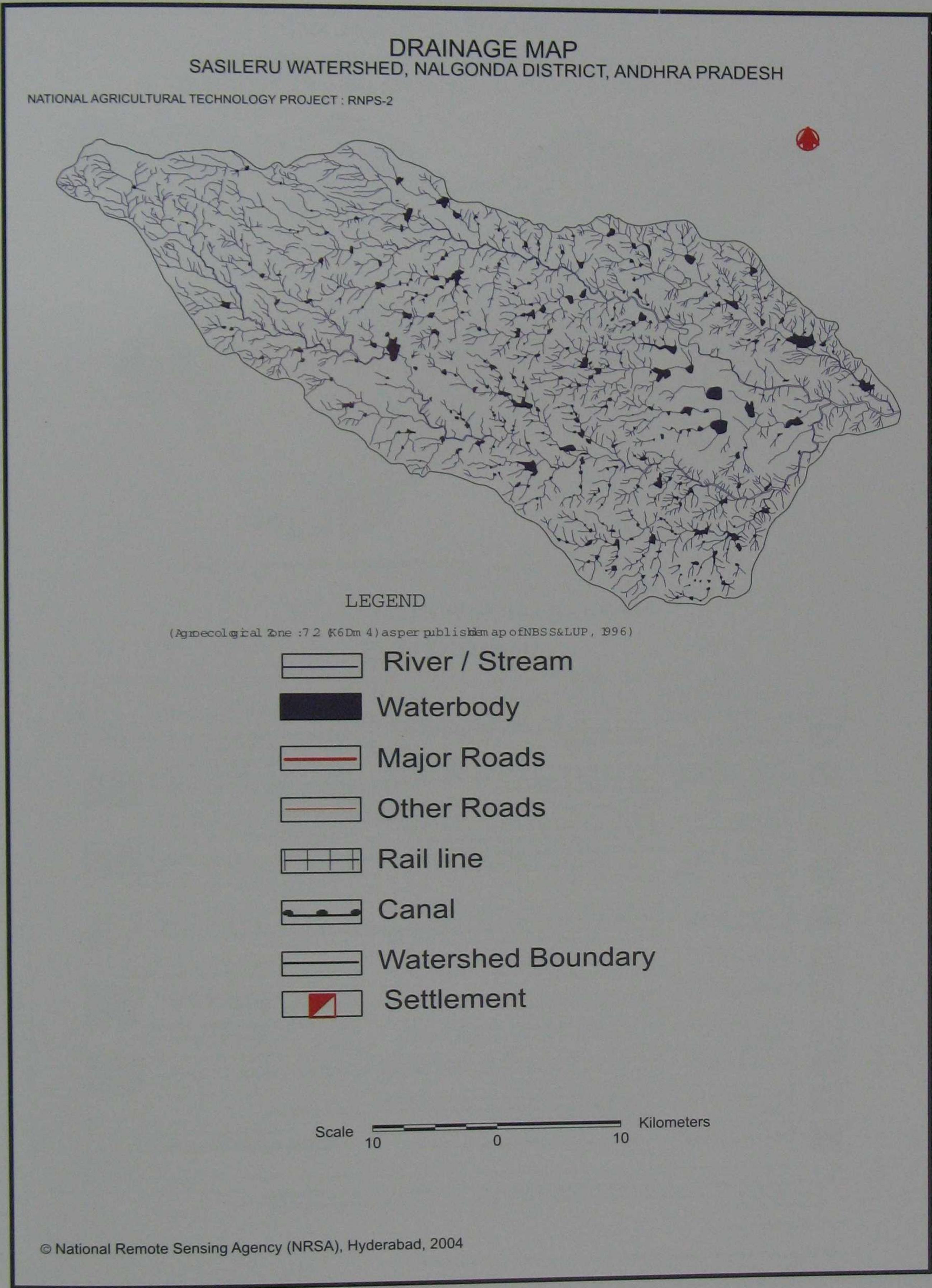
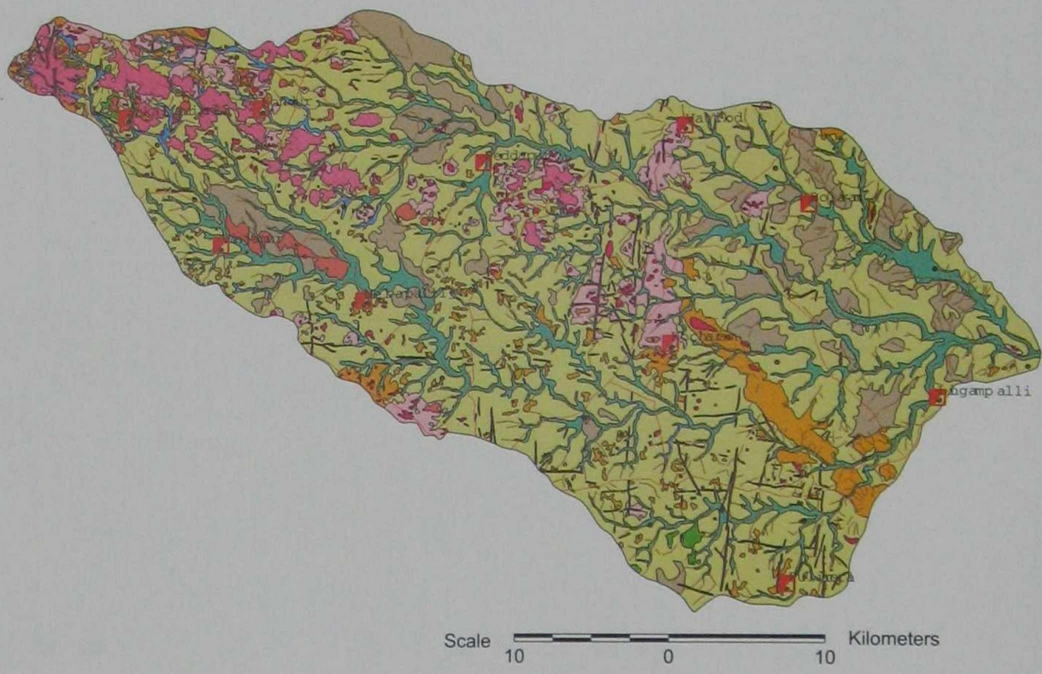


Fig. 3.5 : Drainage map

HYDROGEOMORPHOLOGICAL MAP

SASILERU WATERSHED, NALGONDA DISTRICT, ANDHRA PRADESH



HYDROGEOMORPHOLOGY

LEGEND

Map Symbol	Geomorphic Unit/ Landform	Description	Groundwater Prospects
	Valley Fill-Shallow (VFS)	Formed between high relief/uplands,and comprises of 0-5 mts fill material.	Generally Good.Yields 150-200 lpm.Better prospects supported by fractures/lineaments
	Buried Pediplain-Shallow Weathered (BPS-W)	Formed by the shallow overburden of transported/foreign material on prior pediplain,the thickness of the overburden generally varies between 0-10 mts.	Good to Moderate .Yields 100-150 lpm. Fracture zones are suitable for groundwater exploitation.The area generally comprises of black soil.
	Pediplain - Shallow Weathered (PPS)	Gently undulating plain ; highly weathered with shallow thickness and large in areal extent.Formed by the coalescence of several pediments and inselbergs of ArcheanGranites. The depth of weathering generally ranges between 0-10 mts. The area is relatively upland when compared to PPM.	Good to Moderate .Yields 150-200 lpm.Better prospects along fractures / lineaments.The sites along this zone are good for groundWater exploitation.
	Pediplain Shallow Weathered-Eroded (PPS-E)	Same as PPS,but it is relatively high upland and erosion is dominant.	Moderate to poor. Better prospects along the fractures / lineaments.Fracture zones passing through Pediplain's acts as conduits for ground-water movement.
	Pediplain-Moderately Weathered (PPM)	Gently undulating plain ; highly weathered with moderate thickness and large in areal extent.Formed by the coalescence of several pediments of Archean Granites.The depth of weathering generally ranges between 10-20 mts.	Good to Very Good.Yields 200-300 lpm.Better prospects along the fractures/lineaments.The sites along this zone are good for ground water exploitation.
	Pediment (P)	Gently undulating granitic plain often dotted with rock outcrops,with or without thin veneer of soil cover.	Generally poor,Yields 80-100 lpm.Acts as runoff zone.Prospects limited to fracture/fissure zones.
	Inselberg (I)	Isolated hill of massive type abruptly raising above surrounding plains.Formed by differential erosion.	Acts as runoff zone without any significant recharge or groundwater.
	Pediment-Inselberg Complex (PIC)	Isolated low relief/hillock surrounded by gently sloping, smooth,erosional bed rock with thin veneer of soil cover or detritus.	Poor,Yields 35-50 lpm.Prospects limited to fractures/lineaments and some times controlled by joints.
	Residual Hill (RH)	Formed due to differential erosion and weathering; occupies larger area when compared to inselberg.A more resistant rock formation stand as isolated hill.	Acts as runoff zone.
	Denudational Hill (DH)	Formed due to differential erosion and weathering; occupies larger area when compared to residual hill.A more resistant rock formation stand as isolated hill.	Acts as runoff zone.
	Dyke Ridge (DR)	A narrow linear resistant ridge formed by differential erosion.	Nil.Acts as barrier for groundwater movement.

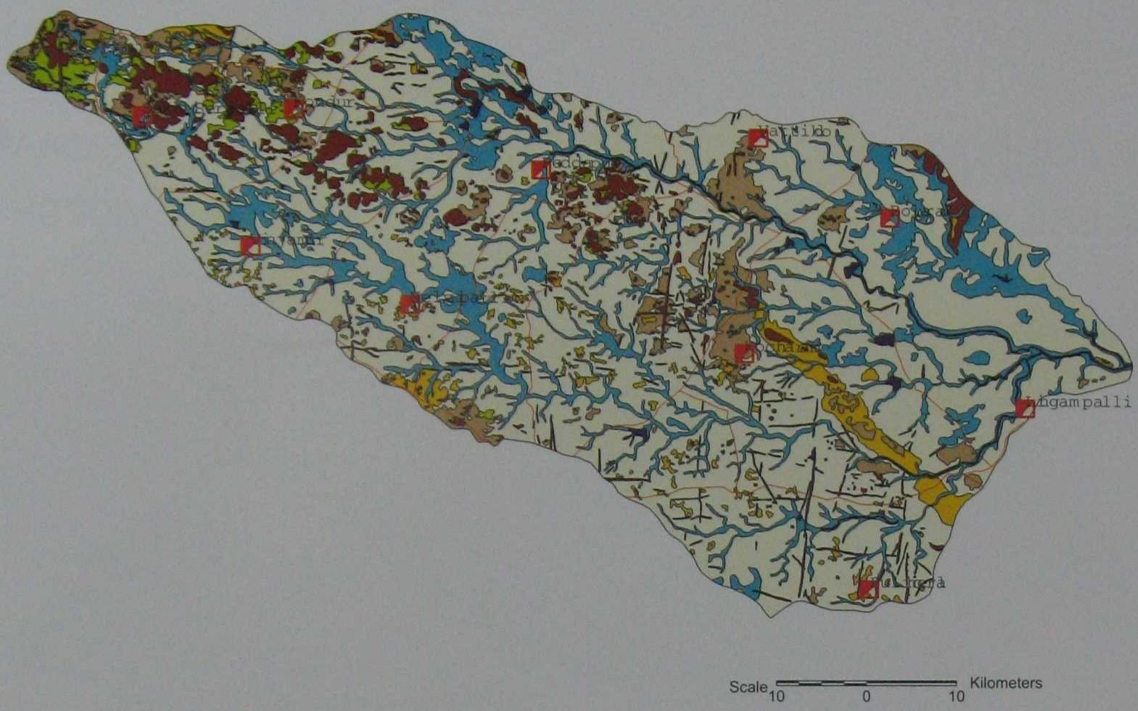
* The overall area of Sasileru Vagu Watershed is having high Fluoride content, which leads to Fluorosis and joint diseases. Ground water prospect is generally good in overall watershed but the quality is poor.The yields shown are approximate, based on field data.

— Fracture / Lineament

■ Groundwater quality; x = Average Fluoride concentration in ppm; y = No. of wells observed

Fig. 3.6 : Hydrogeomorphological map

LAND RESOURCES DEVELOPMENT MAP
SASILERU WATERSHED, NALGONDA DISTRICT, ANDHRA PRADESH

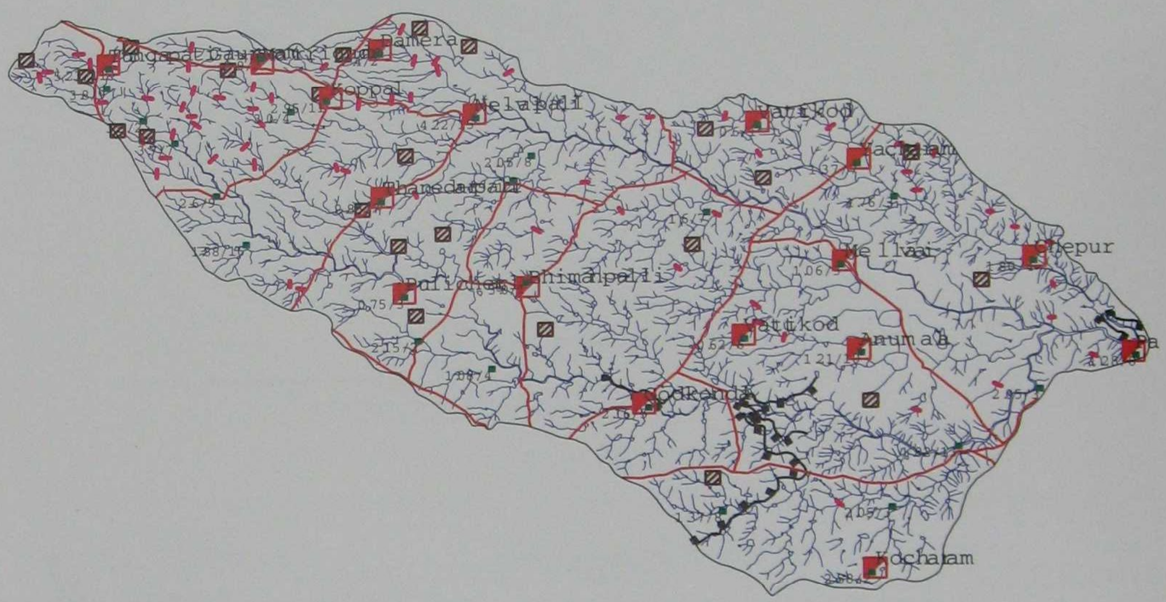


LEGEND

MAP SYMBOL	ACTIONS PROPOSED	AREA (Ha)	AREA (%)
	Soil conservation measures	8062.59	6.15
	Drainage improvement + Growing salt tolerant crops	9341.00	7.13
	Afforestation with soil conservation measures	4939.32	3.76
	Intensive agriculture	24715.70	18.86
	Pasture land with soil conservation	1992.52	1.52
	Improved agriculture	80853.62	61.71

Fig. 3.7 : Land resource development map

WATER RESOURCES DEVELOPMENT PLAN MAP
SASILERU WATERSHED, NALGONDA DISTRICT, ANDHRA PRADESH



Scale 10 0 Kilometers

LEGEND

WATER HARVESTING STRUCTURES RECOMMENDED

CHECK DAM

FARM POND

Gully plugs are proposed wherever suitable mainly on 1st order streams

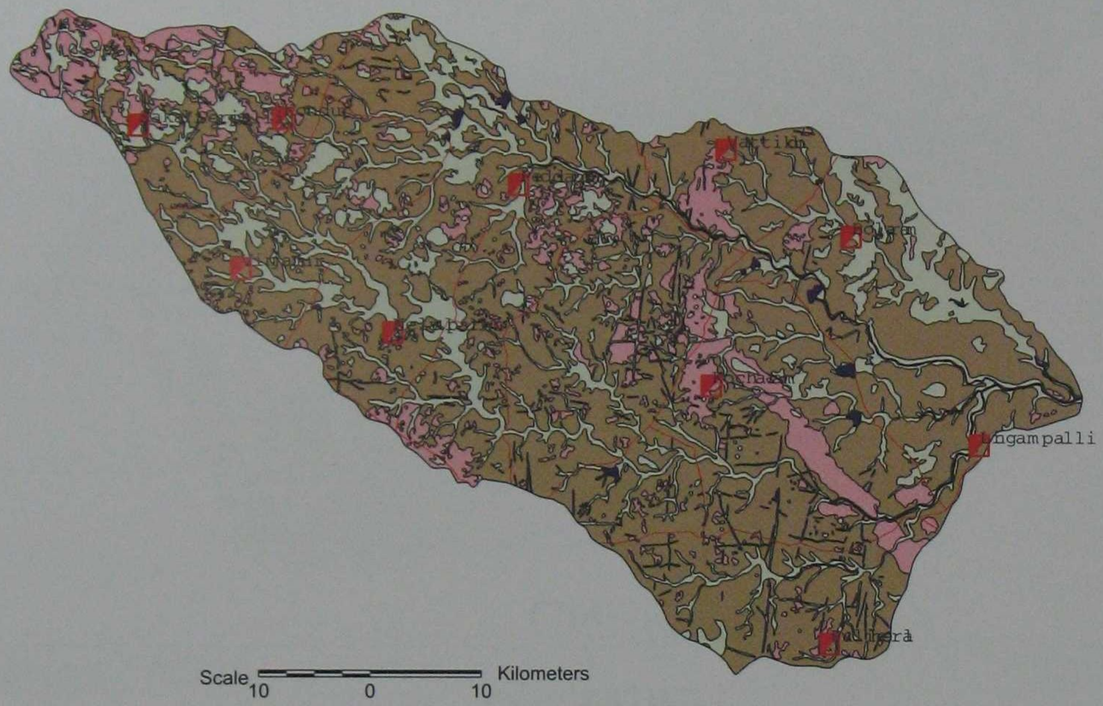
x/y Groundwater quality
x = Average Fluoride concentration in ppm; y = No. of wells observed

Note : The overall area of Sasileru Vagu Watershed is having high Fluorine content, which leads to Fluorosis and joint diseases.Ground water prospect is generally good in overall watershed but the quality is poor.

Fig. 3.8 : Water resources development plan at macro scale

PRIORITY MAP

SASILERU WATERSHED, NALGONDA DISTRICT, ANDHRA PRADESH



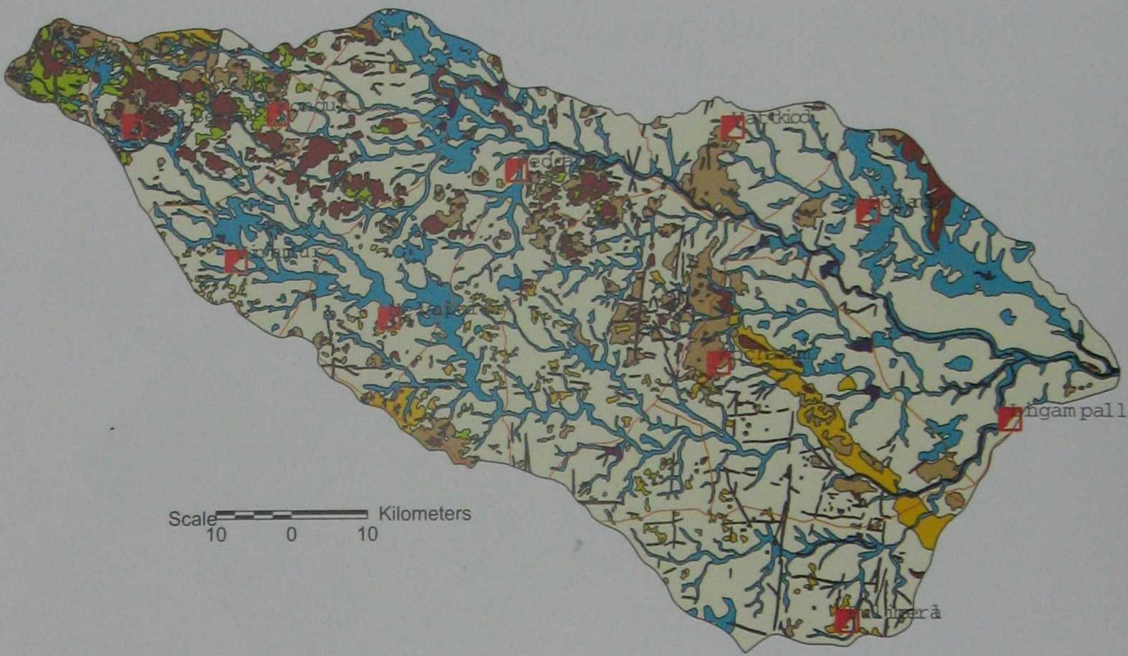
LEGEND

MAP UNIT	LIMITATIONS	AREA (Ha)	AREA (%)
	High	32778	25.01
	Medium	16273	12.42
	Low	80854	61.71

Fig. 3.9 : Priority zones

CRITICAL AREA MAP

SASILERU WATERSHED, NALGONDA DISTRICT, ANDHRA PRADESH



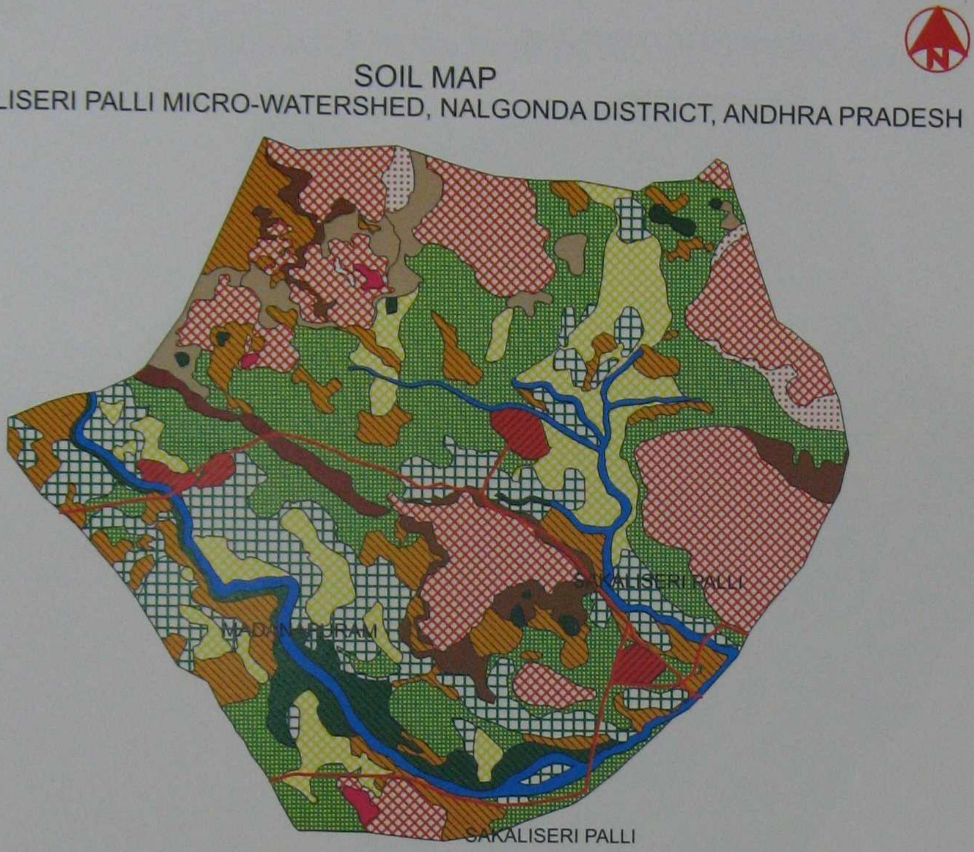
LEGEND

MAP UNIT	LIMITATIONS	AREA (Ha)	AREA (%)
	Very shallow, moderately sloping, severe erosion.	8062	3.7
	Shallow, very gently sloping, moderate erosion.	9341	5.50
	Moderately shallow, very gently sloping moderately erosion	4939	2.5
	Strongly sodic, moderately saline.	2471	19
	Moderately sloping, moderate erosion.	1992	1
	Normal	80853	62

Fig. 3.10 : Critical area map

SOIL MAP

SAKALISERI PALLI MICRO-WATERSHED, NALGONDA DISTRICT, ANDHRA PRADESH



LEGEND

Map Symbol	Soil Unit	Soil Description	Soil Classification	Land Capability sub-class
	G Sak 1eC2	Sakalipalli-1 series, moderately shallow, silty clay loam, gently sloping land (3-8%) with moderate erosion, developed on residual hillside slopes in granitic gneiss.	Loamy skeletal Typic Haplustepts	IVes
	G Tak 1B2	Takkallapalli series, deep, gravelly sandy clay loam, very gently sloping land (1-3%) with severe erosion, developed on hillfoot slopes in a granitic gneiss.	Coarse loamy Typic Haplustalfs	IIIes
	G Ser e B3	Seripalli series, shallow, gravelly clay loam, gently sloping land (1-3%) with severe erosion, developed on dyke/linear ridge and granitic gneiss.	Loamy skeletal Typic Haplustepts	IIIes
	G Kha e B3	Khandunayaka Tanda series, very shallow, gravelly sandy clay loam, very gently sloping land (1-3%) with severe erosion, developed on inselberg of granitic gneiss.	Loamy skeletal Typic Haplustepts	IIIes
	G Bad sB1	Bandamain Tanda series, moderately deep, loamy sand, gently sloping land (1-2%) with slight erosion, developed on upper pediment of granitic gneiss.	Coarse loamy Typic Haplustepts	IIIs
	6G Mad 1sB2	Madanapuram-2 series, moderately shallow, loamy sand, very gently sloping land (1-3%) withmoderate erosion, developed on upper pediment of granitic gneiss.	Fine loamy Typic Haplustalfs	IIIs
	G Sak-2 eB3	Sakalipalli-2 series, very shallow, sandy clay, very gently sloping land (1-3%) with severe erosion, developed on lower pediment of granitic gneiss.	Fine loamy Typic Haplustepts	IIIes

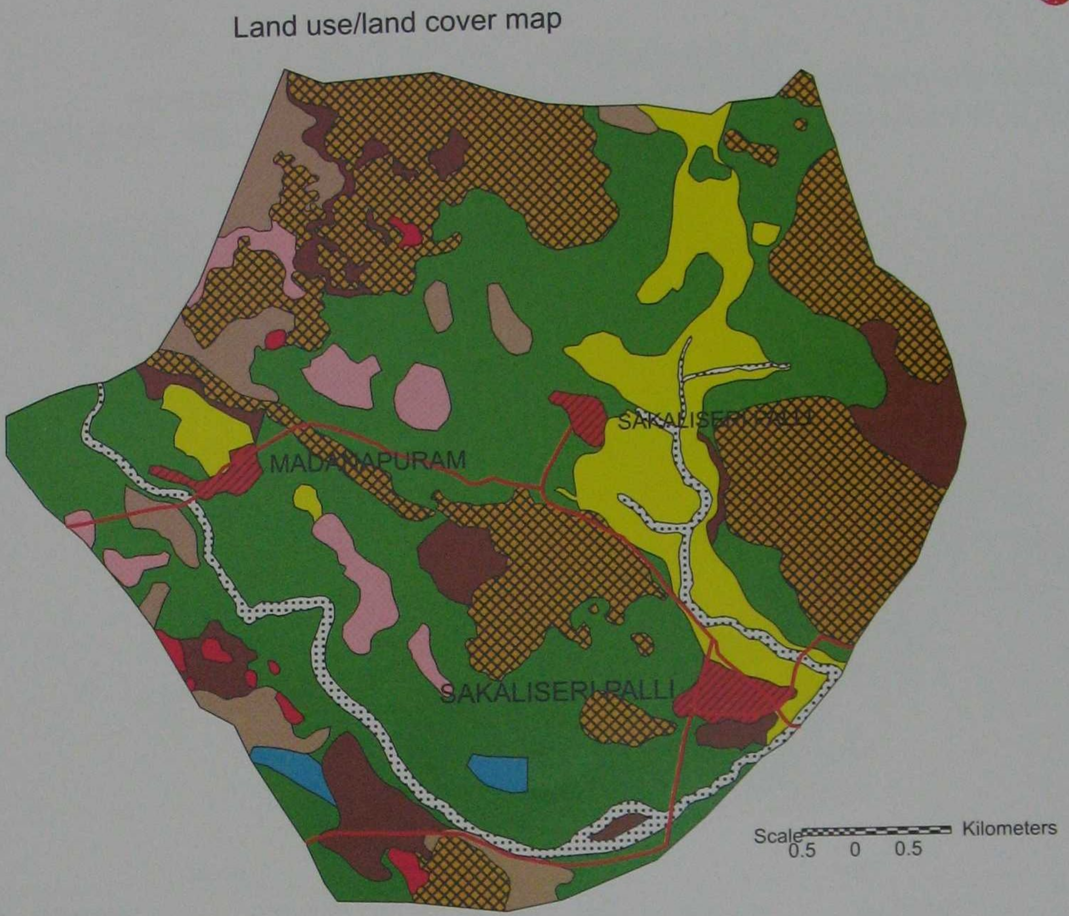
LEGEND

Map Symbol	Soil Unit	Soil Description	Soil Classification	Land Capability sub-class
	G Mad-2 m B1	Madanapuram-1 series, moderately deep, sandy clay, very gently sloping land (1-3%) with slight erosion, developed on pediplain of granitic gneiss.	Fine loamy Typic Haplustepts	IIIes
	G Mad-3 r B2	Madanapuram-3 series, moderately deep, sandy loam, gently sloping land (1-3%) with slight erosion, developed on pediplain of granitic gneiss.	Fine loamy (Calcareous) Typic Haplustalfs	IIes
	G Mad-4 m B2	Madanapuram-4 series, moderately shallow, sandy clay loam, gently sloping land (1-3%) with moderate erosion, developed on pediplain of granitic gneiss.	Fine loamy Typic Rhodustalfs	IIIs
	G Sak-3 e B2	Sakalipalli-3 series, moderately shallow, sandy clay loam, gently sloping land (1-3%) with moderate erosion, developed on valley side slopes.	Fine loamy Typic Haplustepts	IIIs
	G Sak-4 s B2	Sakalipalli-4 series, deep, loamy sand, gently sloping land (1-3%) with moderate erosion, developed on valley of granitic gneiss.	Coarse loamy Fluventic Haplustepts	IIIs

Quarry

Scale Kilometers
0 5 0 0 5

Fig. 3.11 : Soil map at micro level



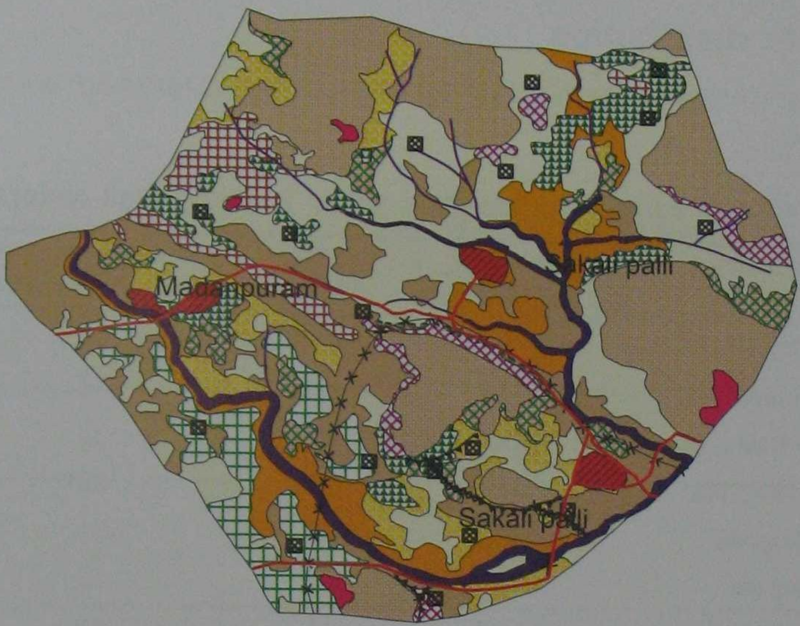
LEGEND

Map Symbol	Level I	Level II	Level III	Area (ha)	Area (%)
	Builtup land	Village		12.62	1.64
	Agriculture land	Crop land	Kharif	329.12	42.99
			Rabi	5.39	0.70
			Kharif + Rabi	71.56	9.34
			Fallow	24.19	3.15
	Waste land	Land with Scrub	-	53.74	7.12
		Land without Scrub	-	40.19	5.24
		Barren rocky/Stony waste/ Sheet rock area	-	197.25	25.76
	Water Bodies	River / Stream	-	26.21	3.42
	Others	Quarry	-	5.22	0.68

Fig. 3.12 : Land use/land cover map at micro level

LAND AND WATER RESOURCES DEVELOPMENT PLAN MAP

SAKALI SERI PALLI MICROWATERSHED ,NALGONDA DISTRICT, ANDHRA PRADESH



LAND AND WATER DEVELOPMENT LEGEND

Map Symbol	Actions Proposed	Area (ha)	Area (%)
	Protection of natural scrub forest and reseeding of grasses	159.88	20.88
	Soil conservation measures, graded bunds, waterways, gabien structures, gully plug, citrus, mango, sorghum+redgram (2:1)	18.88	2.46
	Silvipastoral system with Subabul and Dinanath grass	36.39	4.75
	Agro-horitcultural plantations like mango, guava, orange and Teak with green gram	49.91	6.52
	Construction of graded field bunds, growing of improved sorghum (SPV462) + redgram (LRG-30)	27.63	3.61
	Cultivation of improved sorghum cultivar (SPV462) INM; use of fertilizer (40:30:00)kgs of N, P2O5/ha	173.75	22.69
	Strengthening of field bunds and growing of improved high yielding varieties of kharif sorghum and fodder sorghum	131.72	17.20

Map Symbol	Actions Proposed	Area (ha)	Area (%)
	Calcium loving grass (Sesbania albicans)	42.46	5.54
	Intensive agriculture (improved varieties of sorghum, redgram, castor, vegetables)	54.35	7.09
	No action in the existing unit	23.71	3.09
	Quarry	5.17	0.67
	Continuous contour trenching		
	Proposed diversion channel		
	Proposed drain channel		
	Farmpond		
	Check dam		
	Area of implementation (Nano watershed boundary)		

Scale 0.5 0 0.5 Kilometers

Fig. 3.13 : Land & water resourses development plan at micro level

4.0 Resources of Watershed

4.1 Rainfall and its distribution

The rainfall data of the mandals falling under the watershed was analyzed and presented in table 4.1.

Table 4.1 Analysis of rainfall data of the mandals under Sasileru Vagu watershed

District	Station name	Average rainfall (mm)	CV (%) rainfall	Meteorological drought frequency	Ground water status
Nalgonda	1. Anumula	665.0	28	39	SC
	2. Chintapally	510.6	48	43	OE
	3. Deverakonda	627.8	28	35	OE
	4. Gurrampadu	504.4	38	39	SC
	5. Marriguda	569.6	38	31	OE
	6. Nampally	503.9	49	43	OE
	7. Peddavoora	626.1	29	36	CR
	8. Pochampally	741.7	24	15	CR
	9. Thungaturthy	837.7	24	19	CR
	10. Tirumalagiri	770.2	24	20	CR
	11. Turkapalli	765.9	21	14	OE
	12 P. A. Palli	513.3	36	33	OE
Ranga Reddy	1. Yacharam	679.4	31	38	S
	2. Ibrahimpatnam	650.6	28	35	OE
	3. Manchal	663.8	32	31	S

<u>Note:</u> *OE = Over Exploited (stage of development >100%)*
CR = Critical (stage of development >90%)
SC= Semi Critical (the stage of development 70% - 90%)
S = Safe (stage of development <70%)

The average rainfall of 510 mm (from 1988-2001) was observed in Chintapally mandal and having high coefficient variation (43%) where as the highest average rainfall (837.7 mm) was observed in Thungaturthy mandal with coefficient of variation of 24%. Besides, the ground water status of Chintapally mandal falls under OE category and the meteorological drought frequency is very high (4.3%). Considering the facts as stated above and poor water resource availability, S.S. Pally village under Chintapally mandal was considered as priority area for development. The distribution of rainfall of S.S. Pally village for the 2002 to 2004 is presented in figs. 4.1 to 4.4. It is observed that there is a wide variation of rainfall and its distribution in the mandal and this calls for installation of rain gauge in each revenue village.

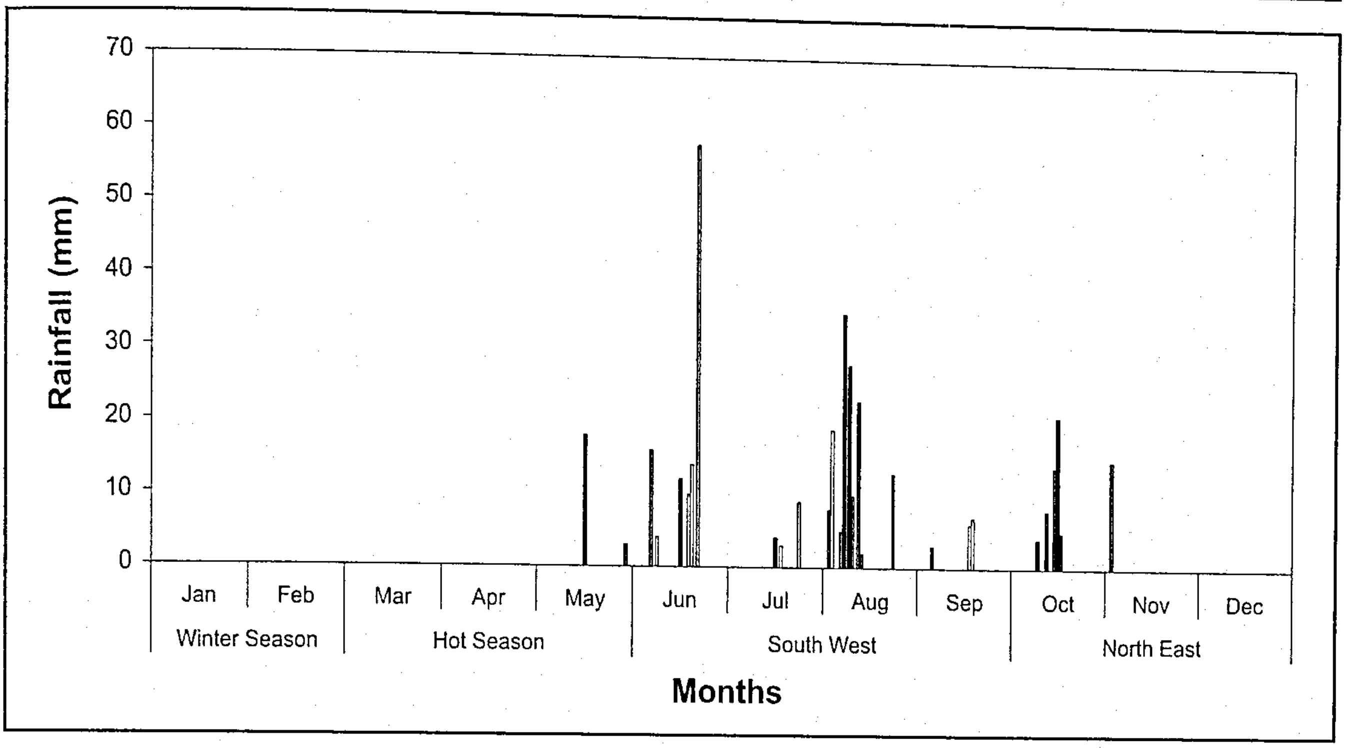


Fig. 4.1 Rainfall during 2002

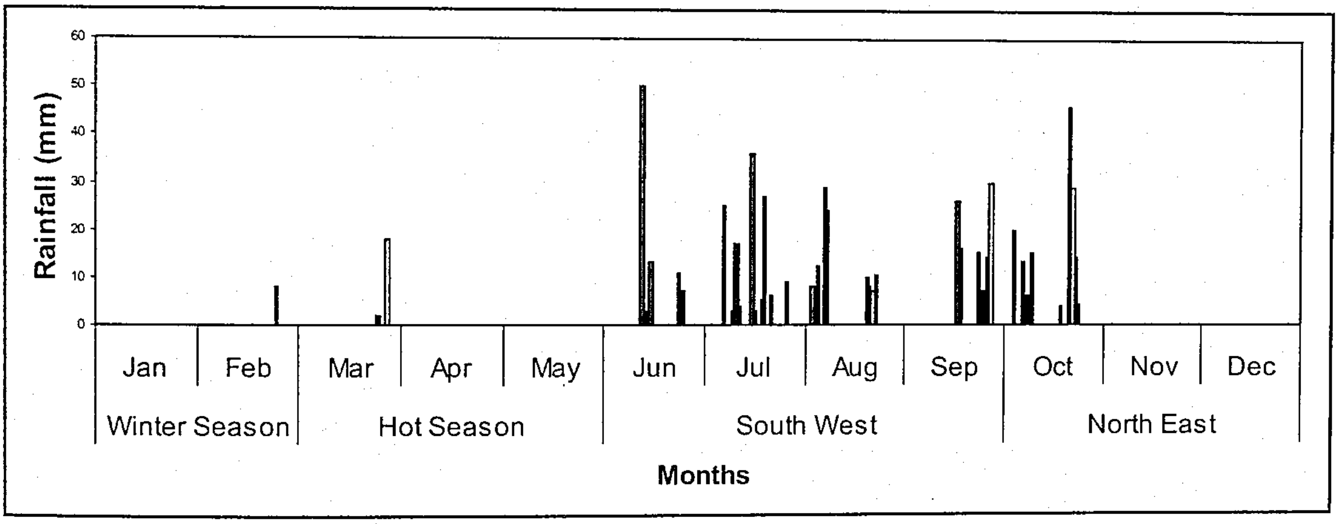


Fig. 4.2 Rainfall during 2003

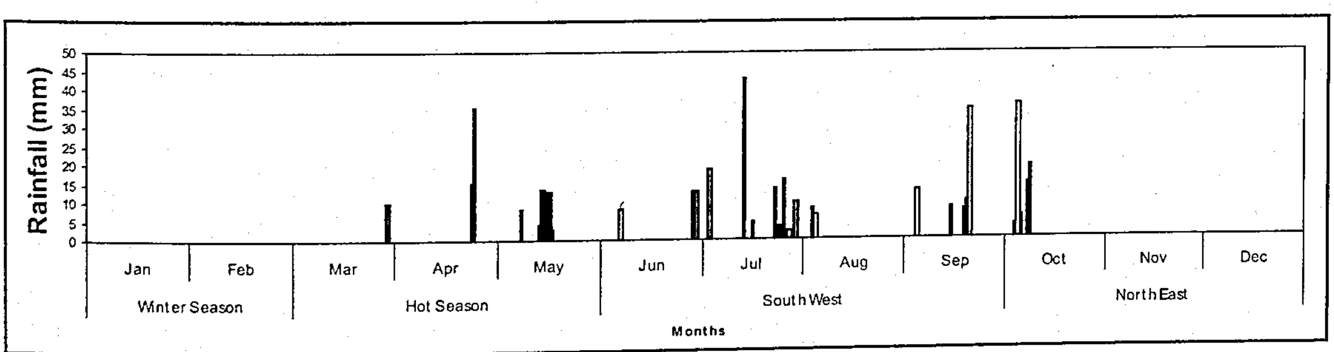


Fig. 4.3 Rainfall during 2004

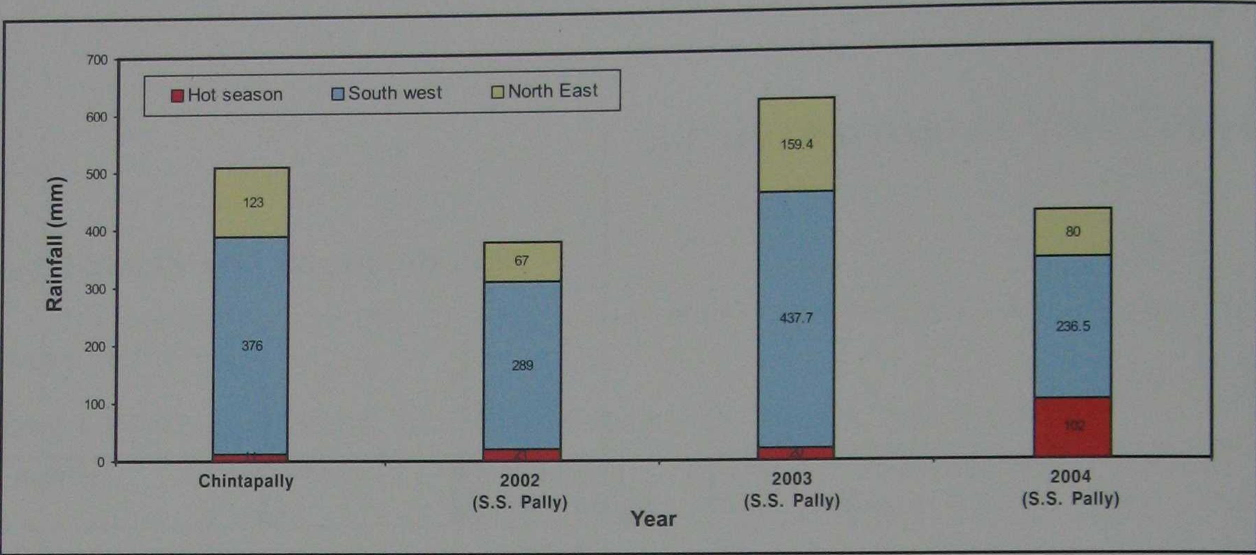


Fig. 4.4 Seasonal rainfall of S.S. Pally compared to average rainfall of Chintapalli mandal

As distribution of rainfall is highly variable, a comparative study of the rainfall of the S.S. Pally village and nearby Gollapally village (situated at a distance of 2 km away from S.S. Pally) was taken up. The analysis showed that the rainfall at S.S. Pally is 13.1% less than Gollapally in 2004. This justifies the installation of rainguage in each watershed village. Further the rainfall of the area was compared with that of nearby Chintapally mandal of rainfall data (Table 4.2). The deviation was as high as -26.1%.

Table 4.2 Distribution of rainfall in the study area with respect to mandal average Rainfall (Chintapally, 510 mm)

S.No	Year	Annual rainfall in the study area	% variation of rainfall with respect to Chintapalli mandal
1	2002	377	(-) 26.1
2	2003	617.1	0.17
3	2004	418.5	(-) 17.9

4.2 Variation in soil properties

Soil testing programs for ascertaining the fertility variations in watershed is key component which will be helpful in adoption of suitable interventions. This step is essential in initial stages of crop production programmes in low fertile soils which would improve the livelihood of farmers through increased productivity. Low fertile soil occupy considerable area in watersheds. Suitable awareness has to be created in the minds of farmers regarding the importance of soil testing. The present study also highlighted the variations in soil fertility status, the interventions taken up and the benefits derived by the farmers in terms of improved crop yield. It also justifies the need for timely soil sampling to realize the benefits.

Soil properties varies with space and time. Hence, soil testing is useful to evaluate soil fertility status and for making fertilizer recommendations as well as for reclamation of problem soils, provided soil samplings were carried at appropriate intervals. Table 4.3 highlights the variation in soil properties as influenced by extensive and intensive sampling at macro-watershed (Sasileruvagu) and micro-watershed (SS pally watershed) level.

The soil reaction showed the presence of alkaline soils when sampled at micro-level in addition to slightly acid and neutral soils at macro-level (Table 4.3). This was reflected in the levels of exchangeable Na and ESP also, where in the soils sampled at micro level has shown a wide range of exchangeable Na. Based on the above results, an intervention was made with the application of gypsum to bring down the soil to a neutral range and to increase the crop yield of castor, which is a major crop in the watershed. The variation in soil texture was also reflected in marginal variation in soil CEC values. Analysis of soil properties with respect to soluble salts, soil organic carbon, available P and K content also signifies the considerable variation as influenced by the sampling interval. Spatial variation at both extensive and intensive sampling suggests for taking up of appropriate management practices such as addition of organic and inorganic inputs, addition of soil ameliorants, adoption of tillage practices and maximization of water use efficiency from the harvested rainwater.

Table 4.3 Variation of surface soil properties as influenced by intensity of soil sampling

Soil Parameters	Sasileru Vagu Watershed (Macro-watershed)	SS pally watershed (Micro-watershed)
pH (1:2.5,w/v)	6.9 – 7.3	6.3 – 8.2
EC (dS m^{-1})	0.21 – 0.62	0.04 – 0.032
OC (gkg^{-1})	2.7 – 6.2	4.3 – 10.8
Soil texture	Coarse/Medium	Coarse/Medium
Sand (%)	49-84	46-79
Silt (%)	2-24	4-11
Clay (%)	2-12	16-31
Avail P_2O_5 (Kg ha^{-1})	10.3 – 12.6	8.1 – 50.4
Avail K_2O (Kg ha^{-1})	304.8 – 605.6	50.3 – 217.1
Exch. Bases (cmol kg^{-1})		
Na	0.15 – 0.86	0.41 – 1.83
Mg	0.3 – 1.9	0.9 – 4.4
K	0.29 – 0.59	0.14 – 1.12
BSP (%)	57 – 94	80 – 97
ESP (%)	2.3 – 4.5	1.1 – 14.6

NB : At micro-watershed level sample was drawn from 1ha gird and at macro-watershed level selective sampling was done.

Fig. 4.5 : Soil organic carbon status in the S.S. Pally micro watershed

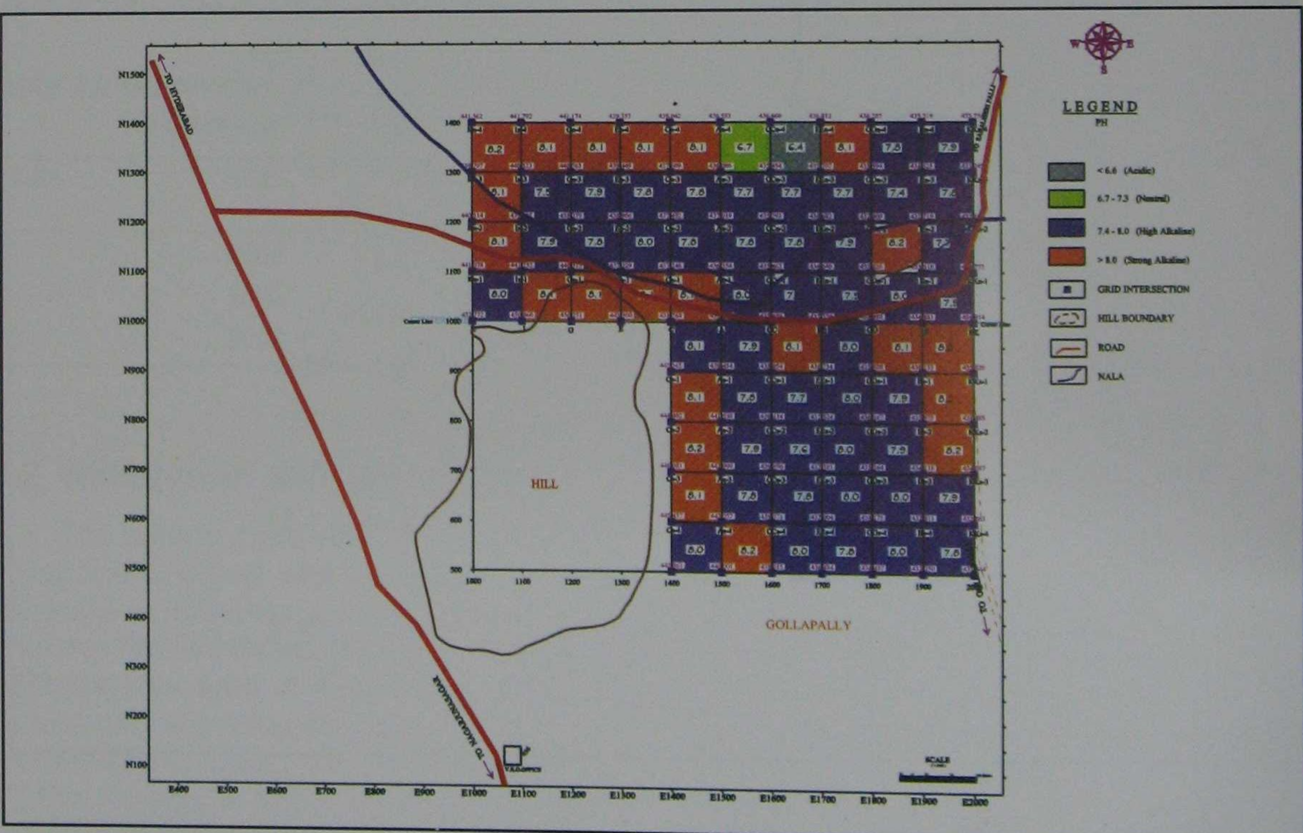


Fig. 4.6 : Soil P^H status in the S.S. Pally micro watershed

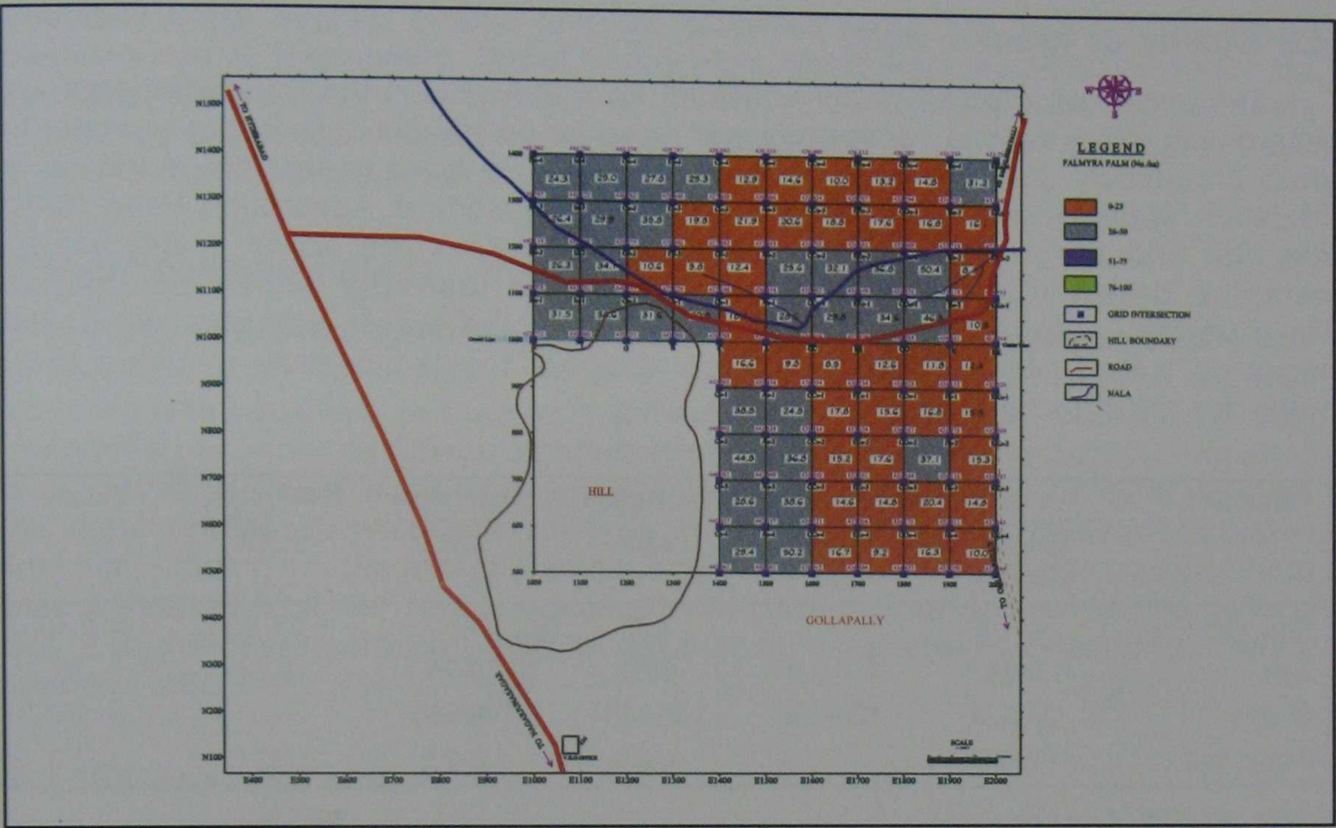


Fig. 4.7: Available P(as P_2O_5) content in the S.S. Pally micro watershed

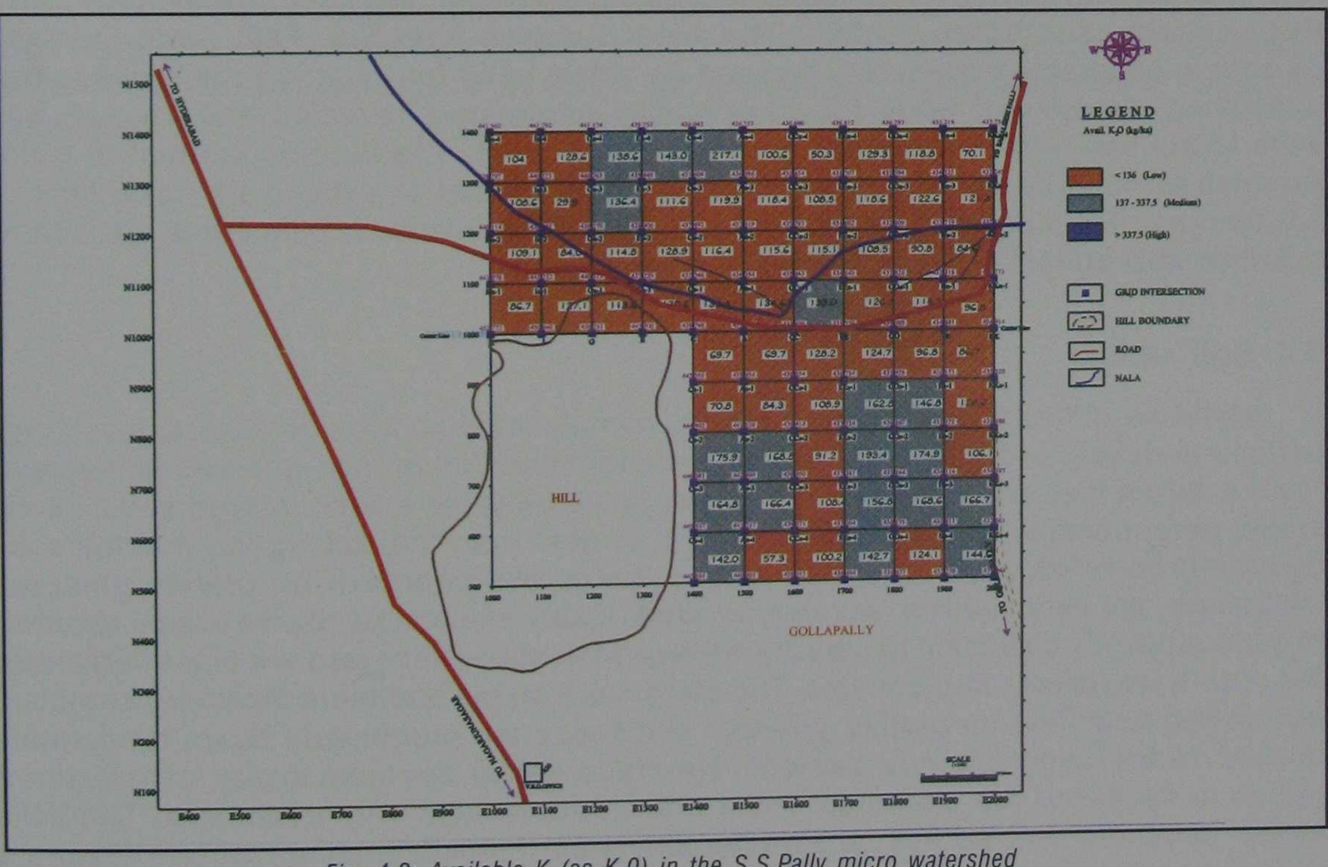


Fig. 4.8: Available K (as K_2O) in the S.S.Pally micro watershed

4.3 Quality of ground water

The quality of irrigation water collected from the wells in the watershed area was also analyzed for various parameters and rated for its suitability as irrigation water for crop production. The following rating class was employed to test the suitability of irrigation water. Residual Sodium Carbonate (RSC), Sodium Adsorption Ratio (SAR), chloride and boron content, were analysed to assess the water quality for the samples drawn from different borewells. Other than the above parameters, the fluoride, sulphate and nitrate contents of the water samples were also analyzed with a view of appraising the villagers to take caution in using those water for drinking purpose.

Parameter	Irrigation water		Permissible / safe	Moderately safe	Moderately unsafe	Unsafe
	Nalgonda n=21	SS Palli n=4				
RSC (me L^{-1})	< 1.0	–	1.25	–	1.25-2.5	> 2.50
SAR	1.0-19.5	3.2-7.3	< 10	10-18	18-26	> 26
Cl (mg L^{-1})	28-228	128-170	< 140	140-350	–	> 350
Boron (mg L^{-1})	0.5-3.6	–	<2.0	2.0-2.5	2.5-3.0	> 3.0

Source : Singh et. al., 1999

Analysis has shown that water samples are neutral in reaction with low soluble salts (data not shown). Based on the ratings with respect to sodium absorption ratio (SAR) and chloride and boron it was found that three sites were found to contain high SAR, RSC, chloride and boron content. The water samples from S.S. Pally were found to be safe in all quality parameters and can be safely used for irrigating the crops in this watershed. Analysis of water for other quality parameters revealed that the samples were found safe with respect to nitrates and sulphates. The fluoride content of water samples at majority sites in Nalgonda district was found to exceed the toxic limit of 1.0 ppm as prescribed by Indian Drinking Water Specifications, hence it is advised to exercise appropriate caution for drinking purpose.

4.4 Soil units

About six different physiographic units, namely residual hill side slopes, inselberg, pediment, dykes, pediplain, and valleys were identified on granite gneissic landscape. Fig 3.4 shows that there are fourteen soil mapping units were encountered and 28 soils series were identified in the study area. It is evident from the soil legend that the soils occurring on residual hill side slopes, inselberg, and pediment on granite gneisses landscape, are very shallow, severely eroded, loamy skeletal to coarse loamy textured in surface, sandy clay loam to clay loam textured in subsurface and are classified under the orders Inceptisols and Entisols. The soil occurs on the pediment inselberg complex, undulating pediplain on granite gneissic landscape are moderately deep, moderately eroded, sandy loamy to sandy clay loam in surface, sandy clay loam to clay loam textured in sub surface and are classified under the orders *Alfisols* and *Inceptisols*, The soils in the pediplain and valleys, are moderately well drained, medium to fine textured, moderately deep, slightly eroded and are classified under the vertic subgroup of *Inceptisols* and as Haplusterts. Out of twenty eight series were identified 17 series are *Inceptisols*, 8 are *Alfisols*, 1 is *Entisols*, and 2 are *Vertisols*.There are four soil orders encountered in the Sasileruvagu watershed. *Inceptisols* is the dominant order and *Alfiosols* is the subdominant soil orders identified in the study area.

4.5 Hydrogeomorphology

The study area represents a true picture of hard rock terrain physiography with residual hills, valleys and plains etc. (Fig. 3.6). Topographically the area is gently undulating with pediplain, pediments, inselberg, dykes and residual hills. A major part of watershed is under pediplains characterized by low lying flat to gently undulating plains, developed over weathered granites and gneisses. In the pediment zone the ground water prospects are poor to vey poor, where as pediplain and valley are classified under high yielding ground water potential zones. The residual hills, dykes, and inselberg zones are classified under very poor category of ground water prospects. The general slope of study area range from 1-8% with elevation ranging between 240 and 500 meters above the MSL.

4.6 Land use/land cover

The major crops viz, sorghum, red gram, castor and cotton are cultivated in the watershed. The total area under the kharif crops is 87581 hectares (66.83%) which consist of sorghum, redgram, castor, cotton, bajra, and vegetables. In rabi the dominant crop is well irrigated paddy and area is 11833 hectares (9.02%), fallow area is 2197 hectares (1.67%) and followed by barren rocky/sheetrock/quarry area of 6963 (5.30%). The remaining areas are waste lands which can be brought under cultivation, if irrigation is provided.

5.0 Preparation of Action Plans - Process

5.1 Land resource development

The resource maps such as, soils, land use/ land cover and geomorphology were used to identify the problems in the watershed for generation of action plans for development of land resources. Fig 3.7 shows the action items recommended in the watershed. The residual hills with severe erosion, very shallow soils, and gently sloping areas were recommended for protection of natural scrubs, reseeding of forest species and grasses. In hill foot slopes and pediments with severe erosion, with moderately shallow soils, soil conservation measure like diversion channels, graded bunds, gabian structures and gully plugs were suggested. In the lower pediment with severe erosion, moderately deep, highly calcareous soil, calcium loving grasses (Sesbania albicons) and Dinanth grasses were recommended. In very gently sloping pediplain with moderate deep soils and slight erosion, strengthening of field bunds and contour/graded bunds were recommended.

5.2 Water resource development

In order to identify various water resources regions and their spatial distribution, potentials and limitations for sustainable agriculture and other usage, individual thematic maps such as geologic structure, lithology, geomorphology, and hydro geomorphology maps were prepared at 1:50,000 scale.After the careful study of individual thematic maps, the natural and logical association of parameters of one theme vis-à-vis those of others was studied superimposing one resource over other. Based on the limitations and potentials of available water resources, the water resources development map was prepared and presented in fig 3.13. Satellite data helps in selecting the suitable sites for construction of water harvesting structures, to improve the recharge of ground water. Based on the ground water prospect map, the water harvesting structures have been suggested at suitable locations. Erdas and Arc/INFO software have been used for integrating various thematic information details to demarcate low and high ground water potential zones. In the pediment zone the ground water prospects are poor to very poor and, pediplain and valley are classified under high ground water potential zones. The residual hills, dykes, and inselberg zones are classified under high run off zones with poor ground water potential.

5.3 Micro watershed resource inventory

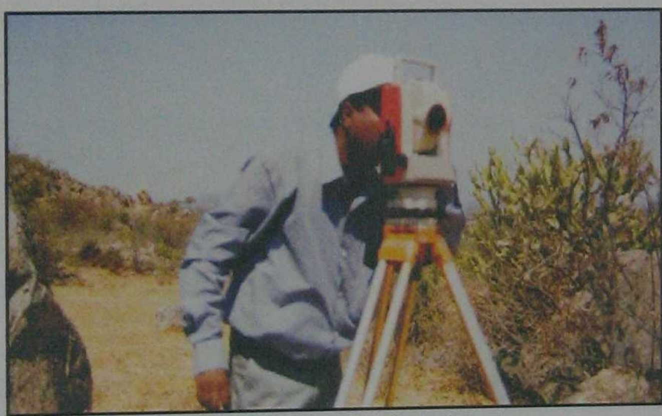
A micro watershed namely, Sakaliseripalli falling under the high priority zone was selected from Sasileruvagu watershed (Figs 3.11, 3.12. & 3.13). It is located 8 kms away from Mal town, and falls in Chintapapalli mandal in Nalgonda District and covers an area of 765 ha. It lies in between 16^0 88' 00'' and 16^0 98' 00" North latitudes and 78^0 70' 00" and 78^0 80' 00" East longitudes. It is covered by survey of India topographical maps 56L/9 and 56L/13.Various physiographic units have been encountered in the study area under different lithological units. Residual hills, pediments, and pediplains are the major physiographic units encountered in the study area. A major part of microwatershed under pediplains developed over weathered granite gneisses. The microwatershed was studied in detail for all the natural resources viz. soils, landuse/land cover, hydrogeomorphology etc. and were mapped at 1:12,500 scale using PAN+LISS-III merged satellite data.Initially the methodology used for watershed development plans was also adopted for identification of critical areas, with a specific action plans at micro watershed level at 12,500 scale.

5.4 Hydrogeomorphology

Topographically the area is gently sloping pediplain with pediments and residual hills. A major part of micro watershed is under pediplain characterized by low lying flat to gentle plains, developed over weathered granite gneisses. In the pediment area, the ground water prospects are poor to very poor and, the pedi plain is classified under high ground water potential zones. The residual hill zone is classified under high run off zone with poor ground water potential.

5.5 Topographic survey and map preparation for 100 hectare area

The cadastral map was collected from the land record office located at Hyderabad for superimposing the thematic and resource maps. The physical features like field boundaries (Survey No), nalas, rock outcrops, roads, wells, high-tension power line and land use etc are demarcated (Fig. 5.1). Topographic survey and grid wise vegetative data is collected at 50 m x 50 m intervals. Topographical survey was conducted using Electronic Total Station. which give an accuracy to 4th decimal i.e. 1/10th part of centimeter, which is most accurate than normal conventional instruments. The elevation was carried from Survey of India GTS Benchmark available nearby at V.R.O. office. Elevation value of benchmark is 436.0 m as per Survey of India toposheet no's 56L/9/NE & 56L/13/NW and Latitude 16^{0}54'21" Longitude 78^{0}44'50". Differential Global Position System (DGPS) was used to extract the latitude and longitude. The same elevation value was transferred to the micro-watershed. The contour survey for micro-watershed was performed based on GTS benchmark on 1 meter contour interval (Fig 5.2). A grid intersection point @ 50 meters interval was laid on total area



Survey using total station

Vegetation Survey

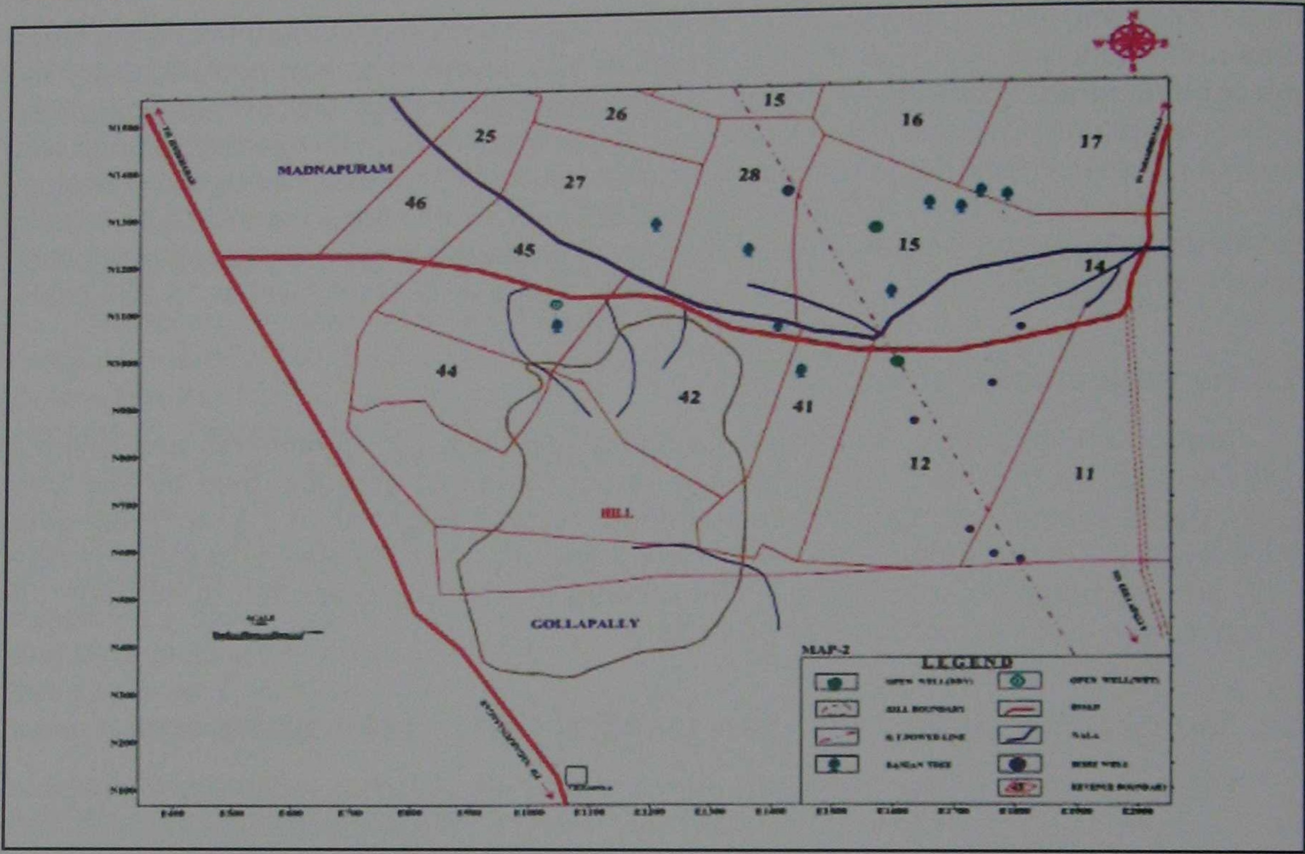


Fig. 5.1 Cadastral map of Sakaliseri Palli micro watershed

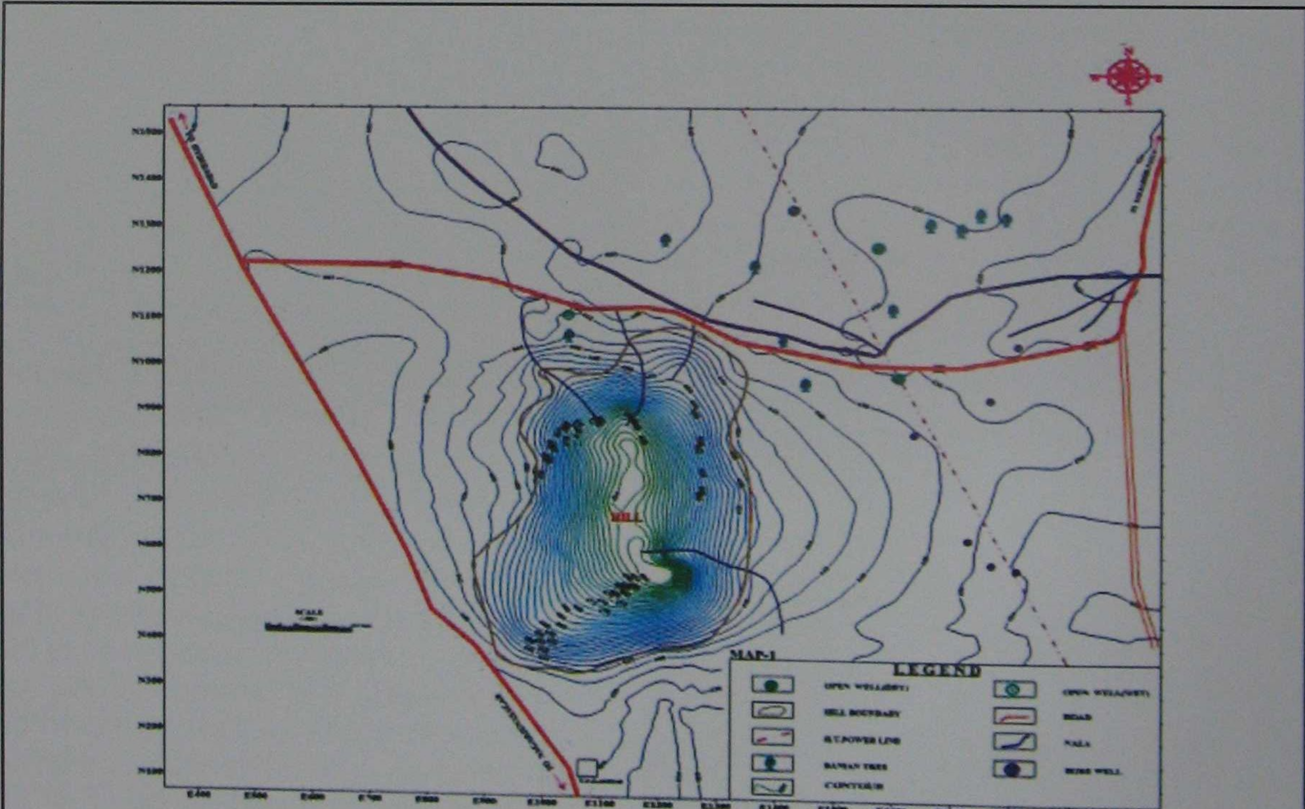


Fig. 5.2 Contour map of Sakaliseri Palli micro watershed

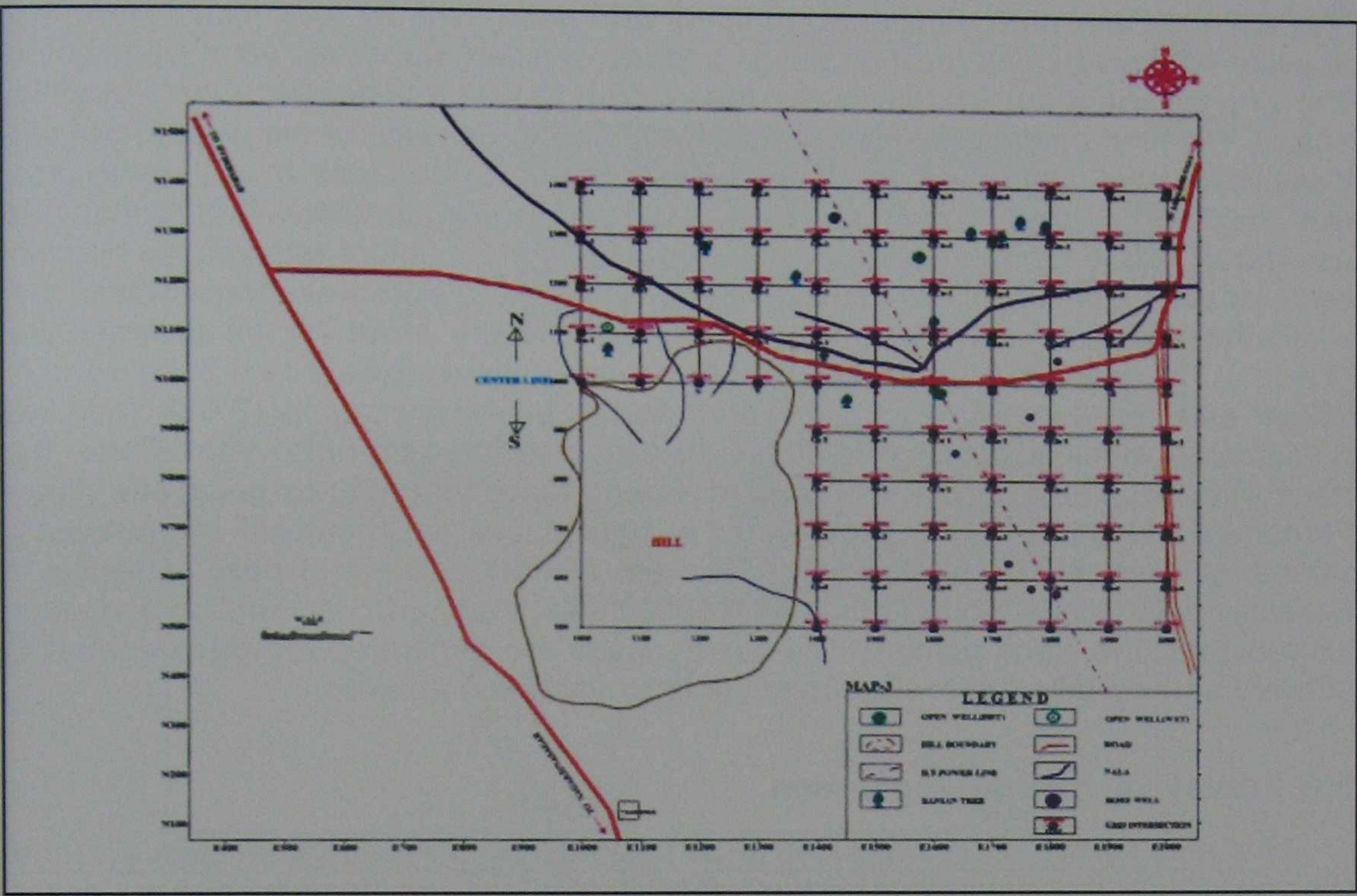


Fig. 5.3 Grid map of Sakaliseri Palli micro watershed

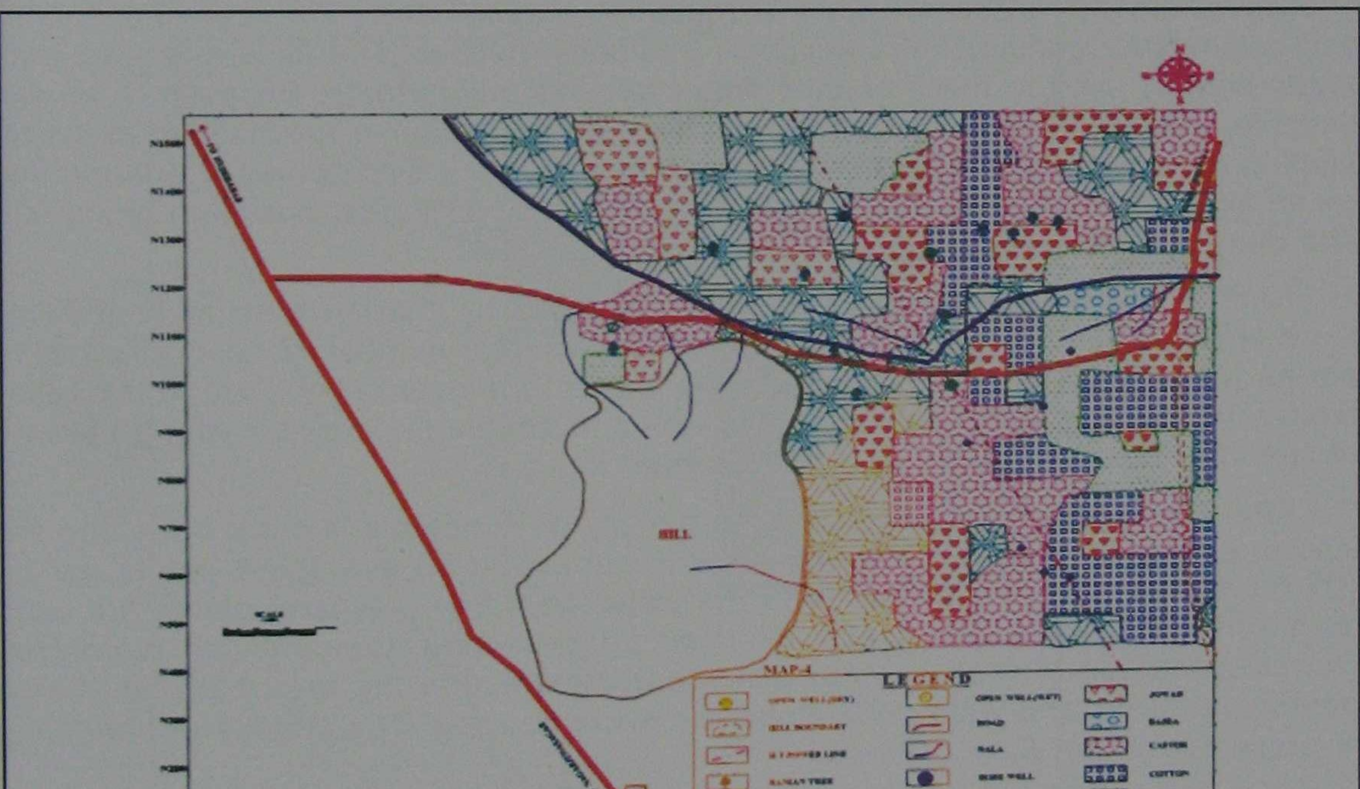


Fig. 5.4 Land use land cover map of Sakaliseri Palli micro watershed

(Fig 5.3) with elevation transferred to every grid point. Granite rock pillars were fixed at every 100 meters grid location points and top of pillars were painted in white colour. The grid numbers are written on the top portion of grid intersection pillars in yellow colour. The land use/land cover survey map (Fig. 5.4) consists of demarcation of crop classification i.e. different types of crops in various field boundaries. In this survey crops like sorghum, paddy, castor, bajra and cotton etc. were identified. Digital maps are generated with different crop classifications, with different colors with various hatching style for easy identification of crops. The open wells and bore wells were demarcated with working wells (wet wells) and non-working wells (dry wells) in total assigned area (Fig 5.1). The main stream, passing from Northwest to towards East near Sakaliseripally village and causeway is also demarcated. Water bound macadam (WBM) road was demarcated which is passing from west to east and diverting north into village. Cart track was recognized from existing Water Bound Macadam road to gollapally village. Permanent Benchmarks are established at four places i.e., near hill at entrance of watershed area, at middle of watershed area, at VRO Office and near causeway of Sakaliseripally village. Soil samples were collected at every grid intersection and coded according to the stone number. The survey maps are generated on digital format for conversion into different format compatible to various softwares.

5.6 Survey of natural vegetation

Grid wise survey of trees was also undertaken during the topographic survey. Toddy (Palmyra Palm) is a naturally growing hardy plant which can draw water from deeper soil layers and resistant to drought condition prevailing in the area (Osman, *et al*, 2000). The leaves of toddy plants are used for thatching purpose and trunk is used as beams and columns for constructing the village traditional houses. The juice extracted from toddy plant is used to make country liquor besides edible fruits. Because of several benefits, farmers retain the plants in their fields and a suitable mechanism exists for tapping of juice (*Kallu*) by the *Goud* community. From the field survey it is found that on an average 24 plants are present in a hectare (CV 93%, the maximum being 93). The density of toddy plantation is presented in fig. 5.6.

Next to toddy, neem trees are largely retained by the villagers in their fields considering its medicinal and timber value. The average number of neem plant is 10 per ha (CV 124%), the maximum being 54. Most of the neem plants are in the valley region between the hills, where slope is less and soil depth is better with a network of streams. The density of neem is presented in fig. 5.7.

After neem the survey show that the density of Pongamia is more but along the stream course where availability of water is better. On an average 6 plants per ha (CV 335% maximum 80) are found in the watershed. The leaves of plants are used as green leaf manure and seeds are used for extracting lubricant and bio-diesel. However, the use of seed has not become commercial in the area but plant has a potential to grow and yield pods along the water courses. The density of pongamia is presented in fig. 5.8.

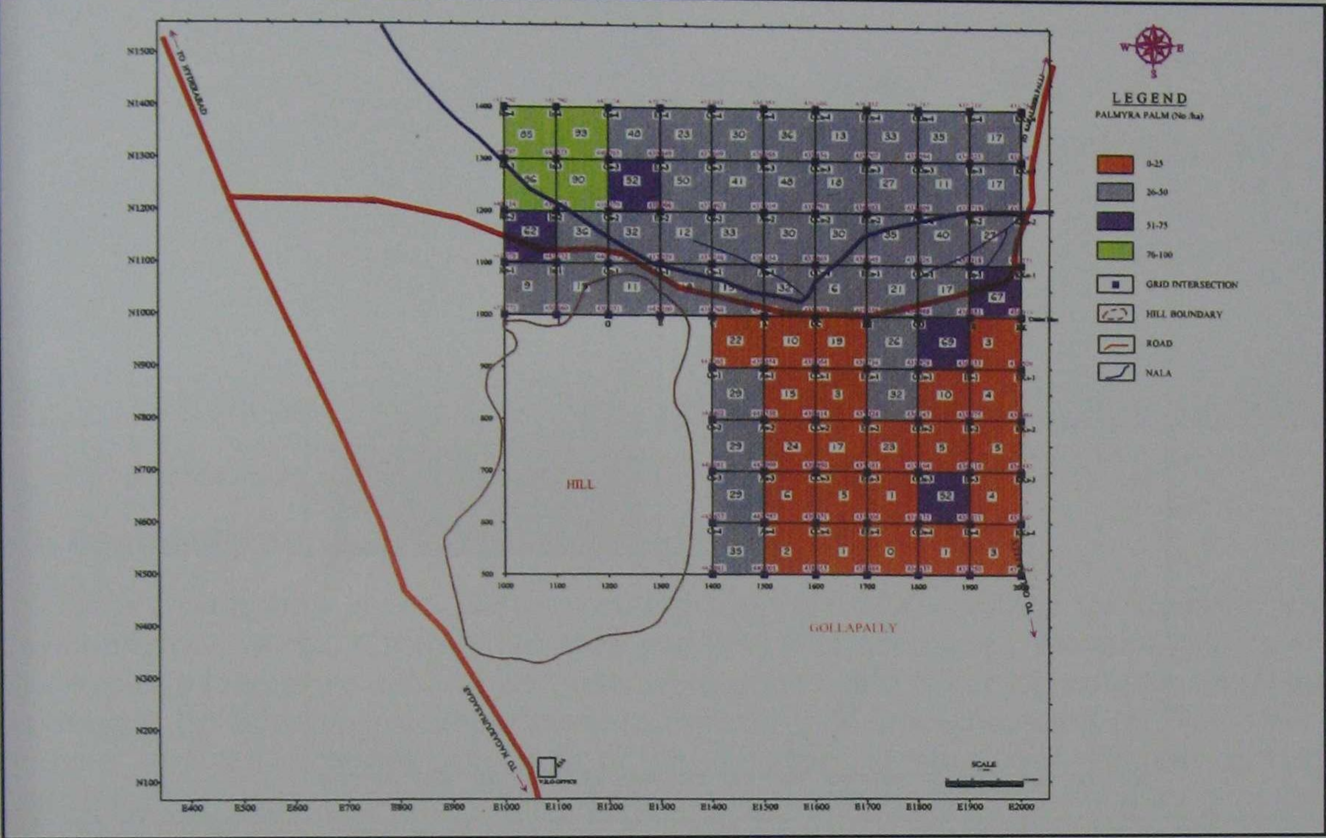


Fig. 5.6: Density (No./ha) of palmyra palm (Borassus flabellifer) in the S.S. Pally micro watershed

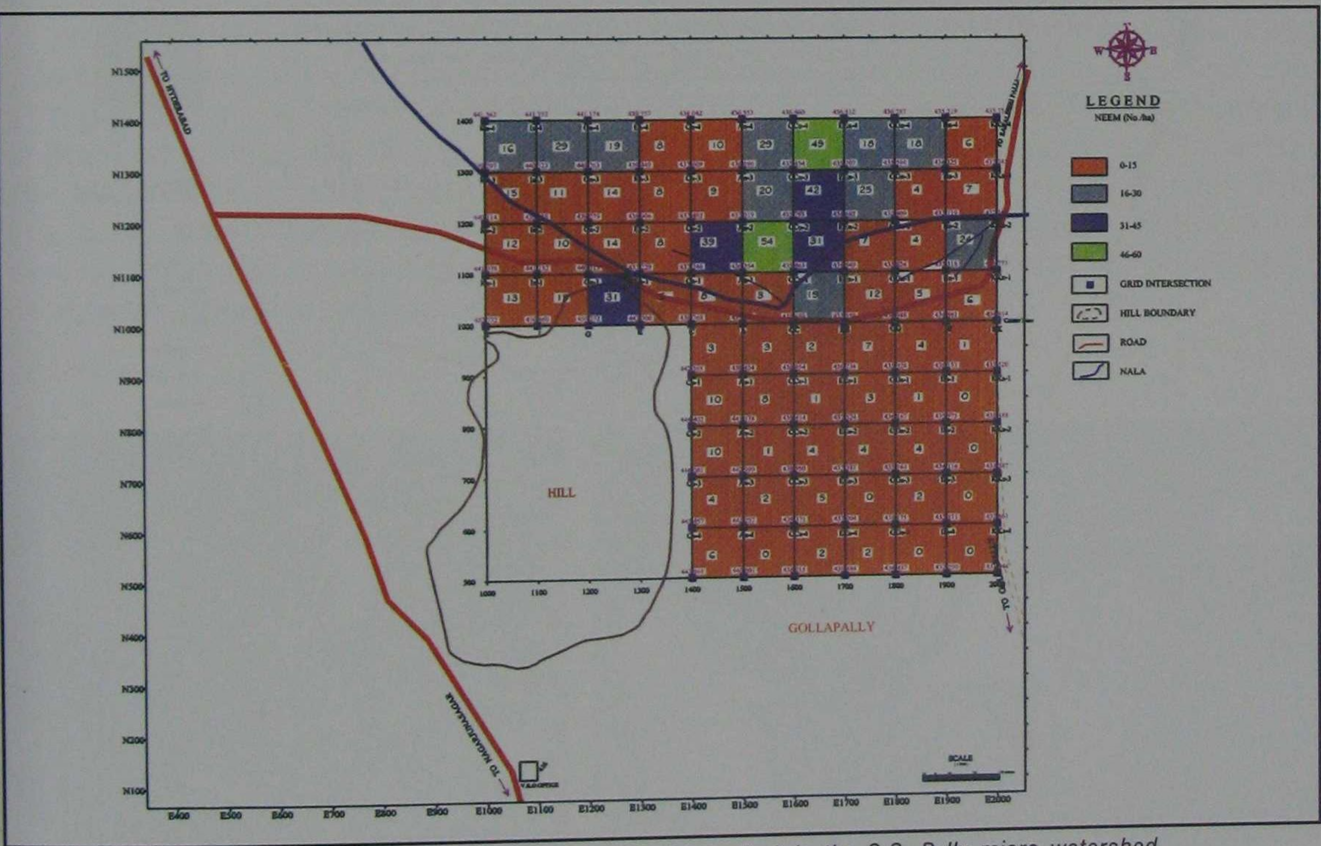


Fig. 5.7: Density (No./ha) of neem (Azadirachta indica) in the S.S. Pally micro watershed

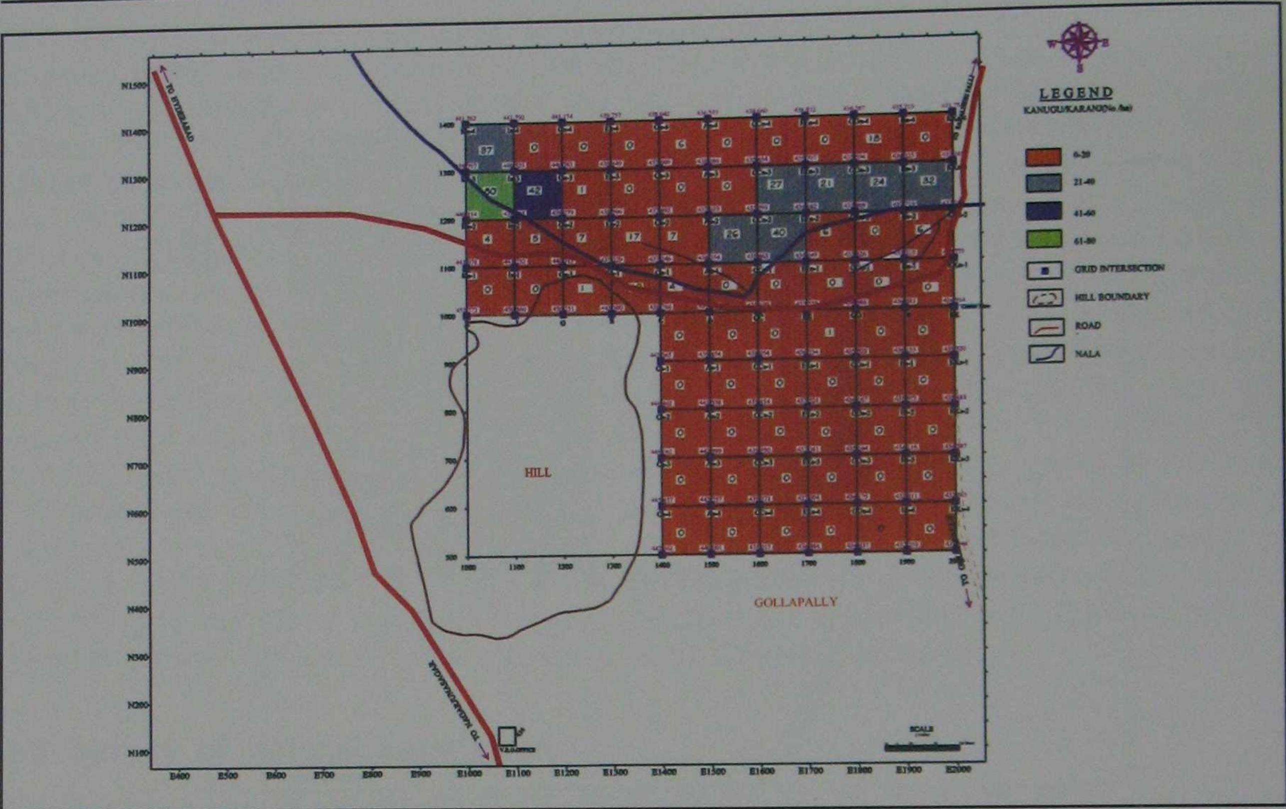


Fig. 5.8 : Density (No./ha) of kanugu/karanj (Pogamia pinnata) in the S.S. Pally micro watershed

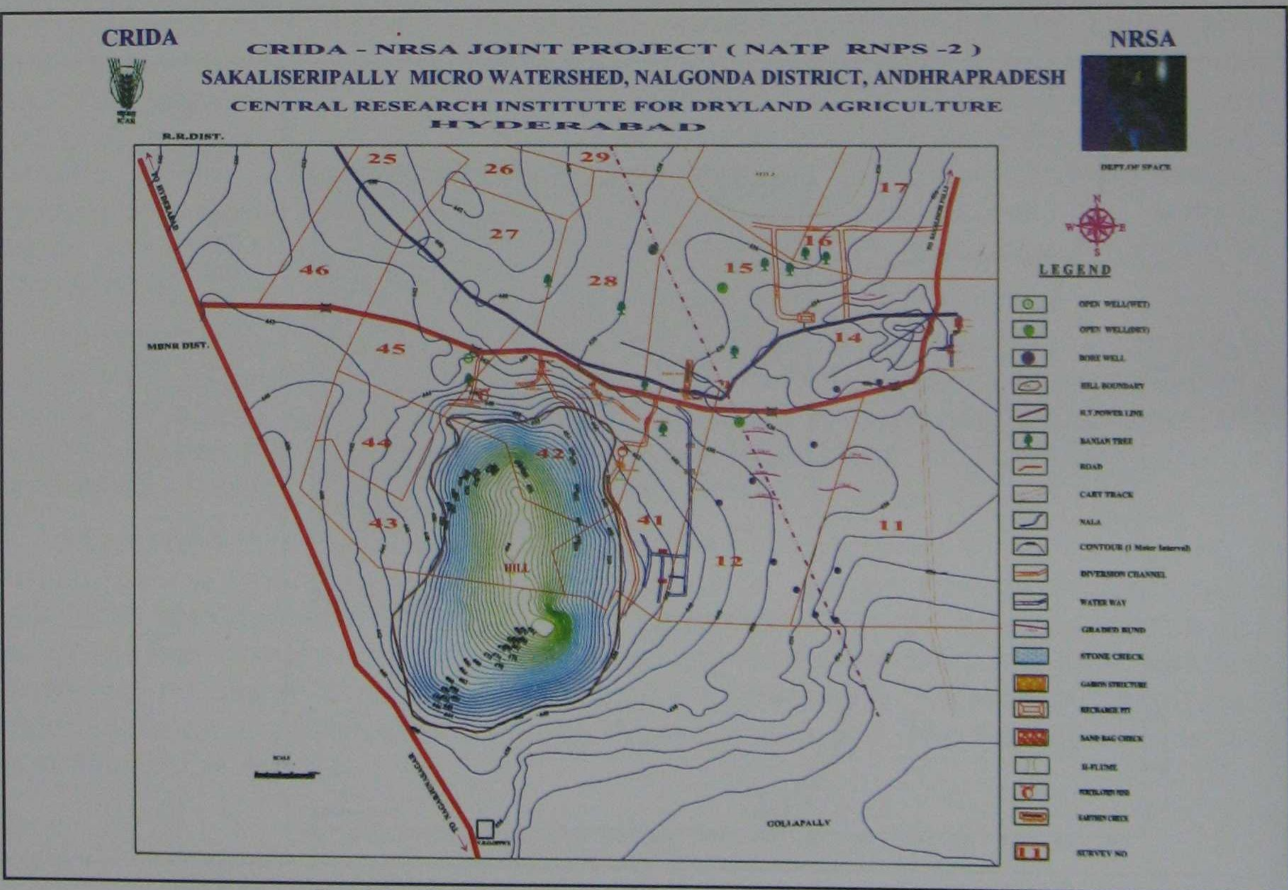


Fig. 5.9 : Soil Conservation structure in S.S. Pally watershed

Fig. 5.10 Demonstration of rainfall simulator: A crowd pulling action learning tool

Fig. 5.11 Runoff from bare and mulched plot coloured water shows more soil loss

5.7 Demonstration of rainfall simulator

Before preparing action plan a meeting was held in the village for finalizing the developmental works in watershed area and PRA was conducted. Demonstrations on the resource losses (runoff and soil loss) were done using twin plot portable simulator developed by Queensland Department of Primary Industries, Australia (ACIAR, 1997) (Figs. 5.10 & 5.11). In the twin plots of the simulator, farmers tried different options like along the slope cultivation, across the slope cultivation and mulching by gliricidia etc. The treatments were subjected to artificial rain through rainfall simulator. At the end of the experiment the villagers themselves measured the runoff volume, depth of wetting front and the colour of runoff water. They themselves concluded that across the slope cultivation and mulching are useful resource conservation measures. They showed interest to adopt cultivation across the slope as a conservation measures and grow gliricidia on the field bund for generating mulch material. Farmers showed interest for planting of trees like Mango, Teak, Sweet Orange and Custard apple etc. The action plan was prepared after thorough discussions with the villagers and conducting PRA (Fig. 5.12). The villagers gave their opinion by writing about the interventions in the meeting in presence of the project staff (Fig. 5.13). The final action plan showing all the interventions was prepared in a participatory mode (Fig. 5.9).

Fig. 5.12 PRA exercise

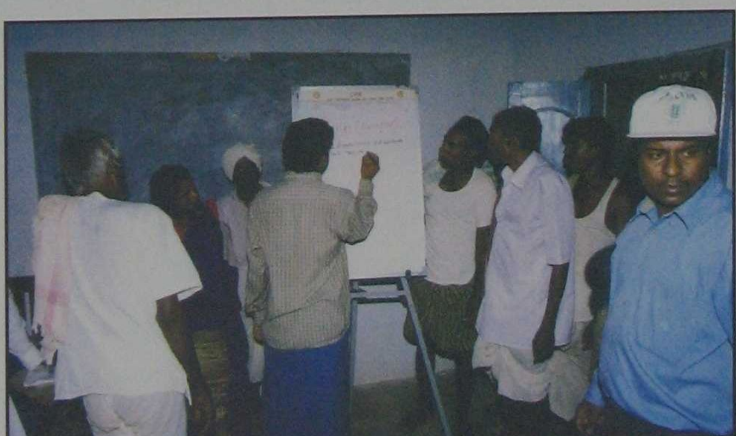


Fig. 5.13 Participatory planning

5.8 Exposure visit

Twenty-five farmers from watershed village were taken to Gunegal research Farm on 6th September 2003 to witness the farmers' day celebration and to interact with the scientist and official and to expose themselves on the dryland technologies. They showed interest to grow sorghum (SPV-462) in their fields with help of CRIDA. The farmers were also taken to near by Gollapally watershed to interact with local farmers. They appreciated the work and wished to have similar activities in their area, particularly the gabion structures (Osman and Mishra, 2003).

5.9 Installation of rain gauge

Two rain gauges were installed (Figs. 5.14 & 5.15) on the rooftop of a farmer's residence in order to create awareness among the farmers of the watershed village for measuring rainfall so that they can timely plan agriculture activities. A village youth was trained to measure the rainfall.

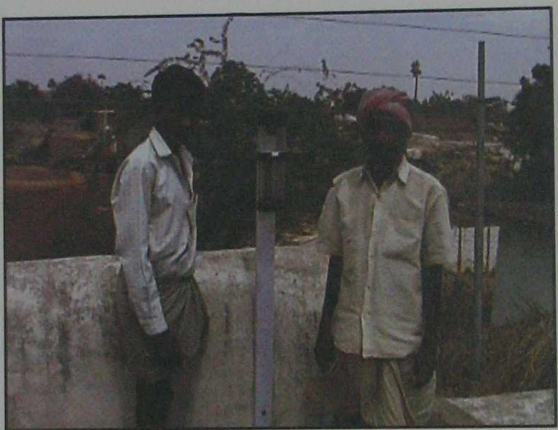


Fig. 5.14 Rain gauge (non-recording) on roof top of farmer's house

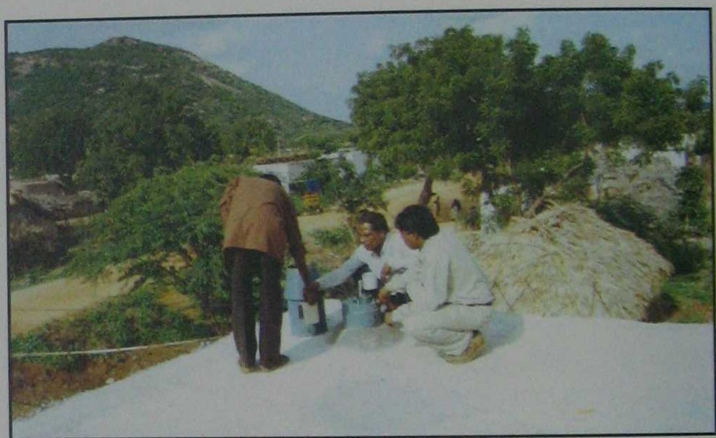


Fig. 5.15 Automatic rain gauge on roof top of farmer's house

The rainfall was above normal in the year 2003 and it was 617 mm as compared to average rainfall of 599 mm of Chintapalli mandal nearest to the watershed. In 2004, the rainfall was 419mm, nearly 32% less than the normal.

6.0 Controlled Experiments using Rainfall Simulator & Tilting Flume

6.1 Experiment with rainfall simulator

A programmable rainfall simulator of 24 m x 3 m developed by CRIDA scientists (Figs. 6.1 & 6.2) was used of to study the effectiveness of different conservation practices in controlled environment (Mishra, *et al.* 2003). Tipping bucket type runoff gauge was used to measure runoff rate and volume. Useful hydrological information like runoff, infiltration, sediment yield etc were generated from runoff plots under different land management practices (Table 6.1).

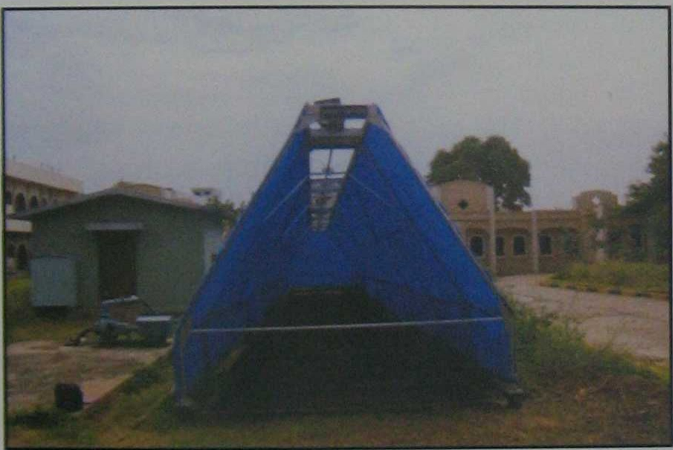


Fig. 6.1 Programmable rainfall simulator

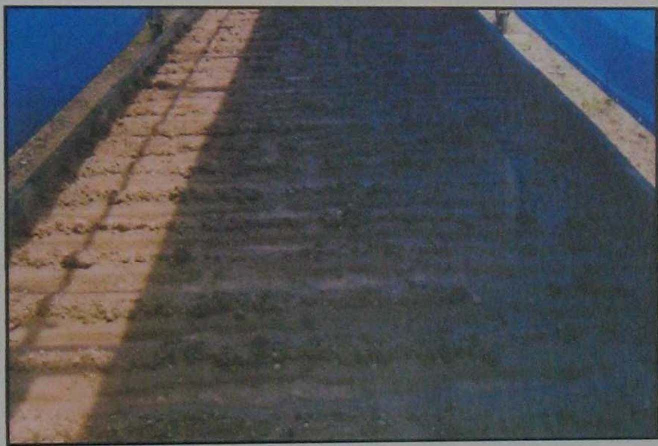


Fig. 6.2 Furrow accross the slope

Table 6.1 Hydrologic parameters as influenced by furrowings along and across slope as compared to bare

Treatment	Time to initiation of runoff (min)	Time to peak runoff (min)	% runoff from soil having saturated antecedent conditions	Sediment loss from a single events of 40 mm (t/ha)
Furrow across the slope at 30 cm spacing	5	19	54	0.6
Furrow along the slope at 30 cm spacing	1	9	69	1.8
Bare land	1	11	63	1.3

The furrows across the slope at 30 cm spacing produced 21.73% less runoff compared to furrow along the slope and 14.28% less as compared to bare land. In case of sediment loss (from single event of 40 mm) it is 67% less as compared to furrow along the slope and 54% less as compared to bare after validating the experiment. CRIDA staff educated the farmers to go for across the slope cultivation instead of along the slope. Farmers also appreciated the practice and adopted slowly furrowing across the slope in their respective fields.

6.2 Experiment using tilting flume

Laboratory study was conducted using CRIDA tilting flume (length 12 m, width 1.5 m and slope variation up to 5%) to evaluate the effect of vegetative cover at 3 meters interval (Table 6.2) with alternative bare and vegetation in the waterways for reducing soil loss, and improving deep drainage (Narshimlu *et al.* 2004). The salient findings are as follows:

- In case of bare soil the sediment concentration (g/l) shows an exponential increase with increase in slope percentage. While comparing the sediment concentration, at 0.1% slope, it was observed that the sediment concentration was reduced by 75% for vegetation cover (*Cenchrus* grass) as compared to the bare soil. At 5% slope the sediment concentration was reduced by 87.5% in case of vegetative cover as compared to bare soil showing the effectiveness of vegetation in reducing soil loss.

- While comparing the flow velocity in case of 0.1% slope, it is observed that the velocity was reduced by 72% for grass cover. At 5% slopes the velocity was reduced by 106% in case of grass cover compared to bare conditions

- While comparing the deep drainage (% in flow) in case of 0.1% slope, it was observed that the deep drainage is increased by 27% for grass cover. At 5% slope the deep drainage is increased by 80% in case of vegetation cover as compared to the deep drainage in bare soil.

- Rill formation was observed at 3% bed slope and above for bare soil, and at 5% slope for grass cover. This gives an insight to erosion control measures.

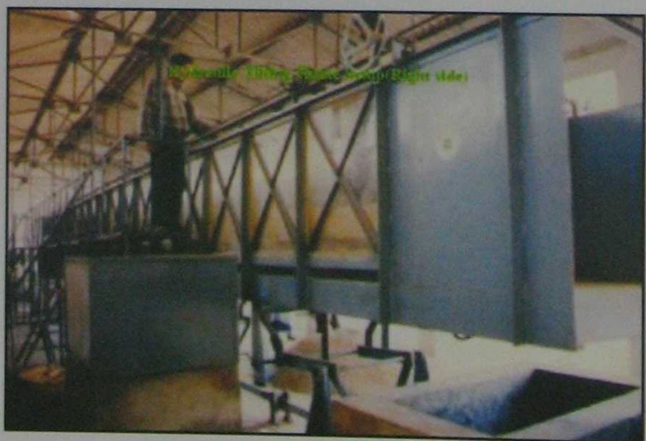


Fig. 6.3 Hydrualic tilting flume

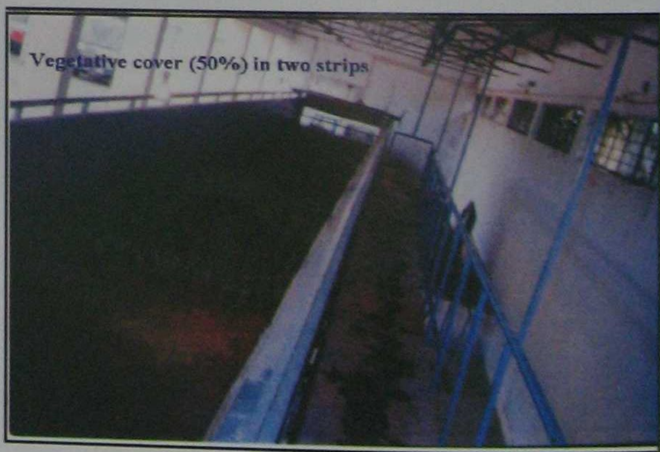


Fig. 6.4 Experiment with vegetative cover

Table 6.2 Relationship between slope (%) and sediment concentration (g/l), velocity (m/sec) and deep drainage (% inflow)

Relation between slope (%) Vs. sediment concentration (g/l)		
Slope (%)	Bare soil	Grass cover
0.1	0.71	0.73
1	4.34	1.19
3	19.66	3.65
5	44.98	8.11
Relation between slope (%) Vs. Velocity (m/sec)		
Slope (%)	Bare soil	Grass cover
0.1	0.36	0.11
1	0.49	0.23
3	0.83	0.45
5	1.25	0.60
Relation between slope (%) Vs. deep drainage (%inflow)		
Slope (%)	Bare soil	Grass cover
0.1	9.9	13.86
1	6.5	10.25
3	1.7	4.83
5	0.7	3.01

The above results indicate that waterways/diversion channel can be vegetated by grass up to 50% of the area to reduce soil loss and improve ground water recharge.

7.0 Soil and Water Conservation Measures

Chalka and *dubba* soils are highly prone to soil erosion and predominant in the study area. The soil organic carbon is low and the soils are poor in nitrogen and are highly deficient in phosphorus. Conservation structures are backbone for watershed activities to protect top soil from further erosion as discussed in the watershed manual (Singh *et al.* 1990). Work done relating to soil & water conservation activities in the watershed is given in table 7.1.

7.1 Design of hydraulic structures

A conservative hydraulic design was made considering the rainfall intensity of 50 mm/hr instead of conventional value of 100 mm/hr or more. This will be adequate for small hydraulic structures at field level (gully control structure, waterways, diversion channel and drop structures). After monitoring the intensity of rainfall and runoff it is concluded that cross section of 0.36 m^2 is safe from hydraulic design point of view.

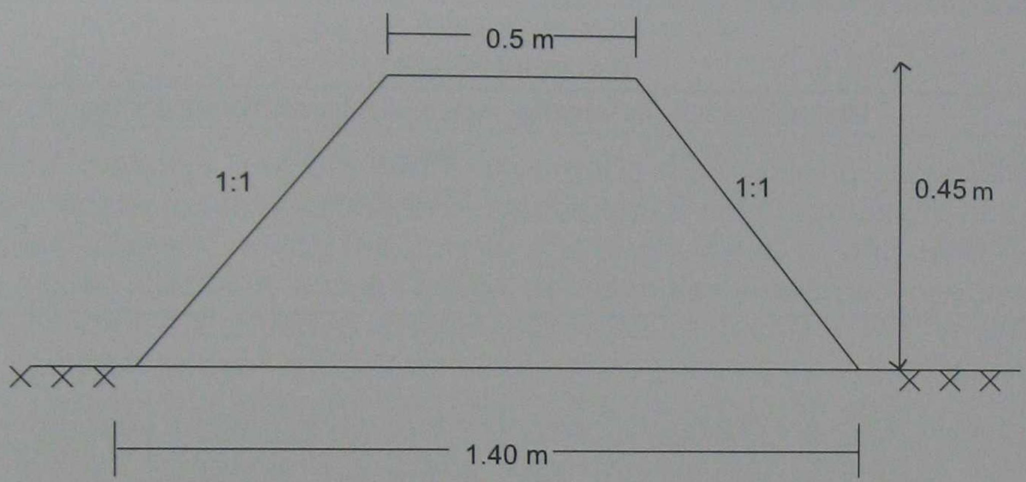
Table 7.1 Completed work in the micro watershed

S.No.	Item of work completed	Quantity/No	Amount spent (Rs)
1	Installation of H-Flumes and stage level recorders	3 No.	10,500
2	Construction of gabion structure	18 No	16265
3	Stone pitching at channel meandering, spill ways, diversion channel percolation tank	100 m^2	6400
4	Water ways	808 meters	12820
5	Diversion channel	1013 meters	16738
6	Percolation pond	1 No. (Each 150 m^3 capacity)	2871
7	Bunding	285 meters	2751
8	Recharge pit	3	2365
9	Construction of loose boulder structure	15 Nos.	4087
10	Construction of (making) Graded Bunds (Av. Cross section 0.38 Sq. mts.)	221	2445
11	Construction of percolation tanks with outlets and stone pitching of embankment (200 cum. capacity)	2	17500
12	Construction of recharge pit and fixing P.V.C. pipe for recharging abandoned well.	1	1950
13	Stone pitching of embankments, Bride heals etc. (Rs. 60/- sq.mt.)	30	1800
14	Sand bag check	1	700
		Total	**99192**

The structural aspects (standard design) of different conservation measures are presented in detail. The designs were based on the Rational formula, Manning's formula and field situations.

7.1.1 Field bund

Contour bunds are recommended for conserving water and graded bund is recommended in high rainfall and ill drained area for safely disposing excess water. It was difficult to dismantle the existing field bunds to construct contour bunds at regular intervals. Therefore the field bunds across the slope were constructed as desired by the farmers with following specification to serve as boundary bunds.



* Diagram not to scale

Cost estimation per running meter (digging & shaping)			
Top width	= 0.50 m	Bottom Width	= 1.40 m
Depth	= 0.45 m	Side slope	= 1:1
Cross Section	= 0.42 m^2	Longitudinal bed slope	= 0.2 %
Cost of construction per running meter = Rs. 13.50/-			

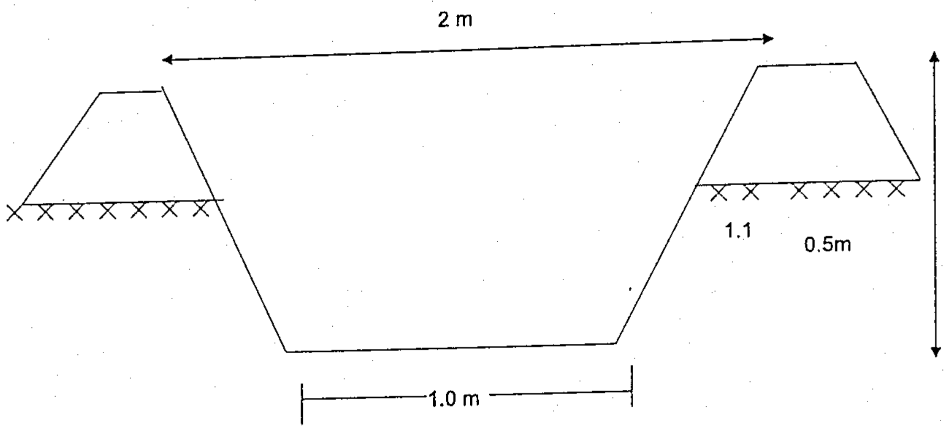
7.1.2 Diversion channel

The diversion channels are constructed across the slope for the purpose of intercepting runoff and conveying it out with safe velocities. The specific purpose is

- ❖ to divert water away from active gully and
- ❖ to protect bottom crop land below the hillocks from erosion.

The dimensions are as follows


Fig. 7.1 Diversion channel in watershed area



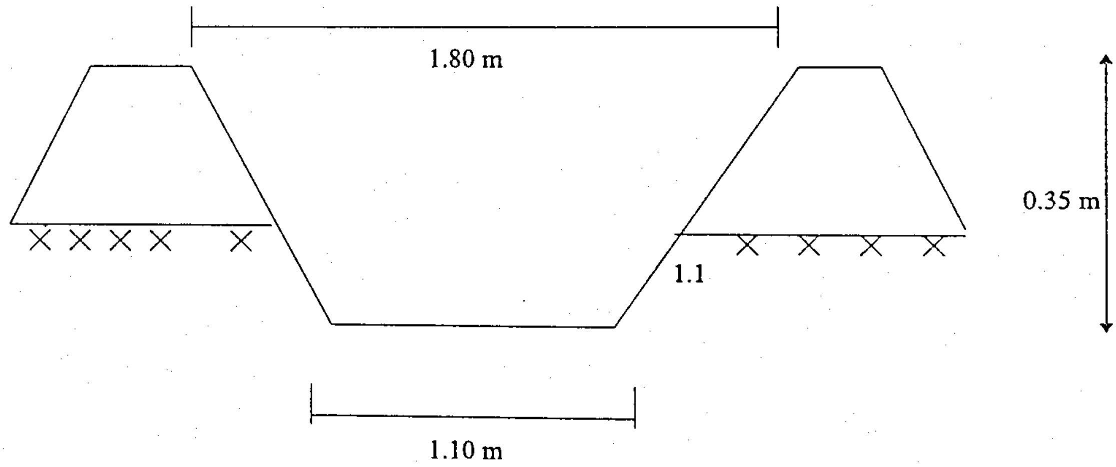
Diversion channel

* Diagram not to scale

Cost estimation per running meter (digging & shaping)			
Top width	= 2.0 m	Bottom Width	= 1.0 m
Depth	= 0.5 m	Side slope	= 1:1
Cross Section	= 0.75 m^2		
Cost of construction per running meter = Rs. 30.50/-			

7.1.3. Waterways

Grassed waterways are drainage channels either developed by shaping the existing drainage ways or constructed separately for effecting drainage of agricultural lands. They are aligned along the major slope to handle runoff from contour/graded bunds, bench terraces, contour trenches and contour furrows. They are helpful in reclaiming the area from gullying and silting. The waterways are designed to pass the flow in a non-erosive velocity in the range of 0.3 – 0.6 m/sec.



* Diagram not to scale

Cost estimation per running meter (digging & shaping)			
Top width	= 1.80 m	Bottom Width	= 1.10 m
Depth	= 0.35 m	Side slope	= 1:1
Cross Section	= 0.50 m^2		
Cost of construction per running meter = RS. 16.00			

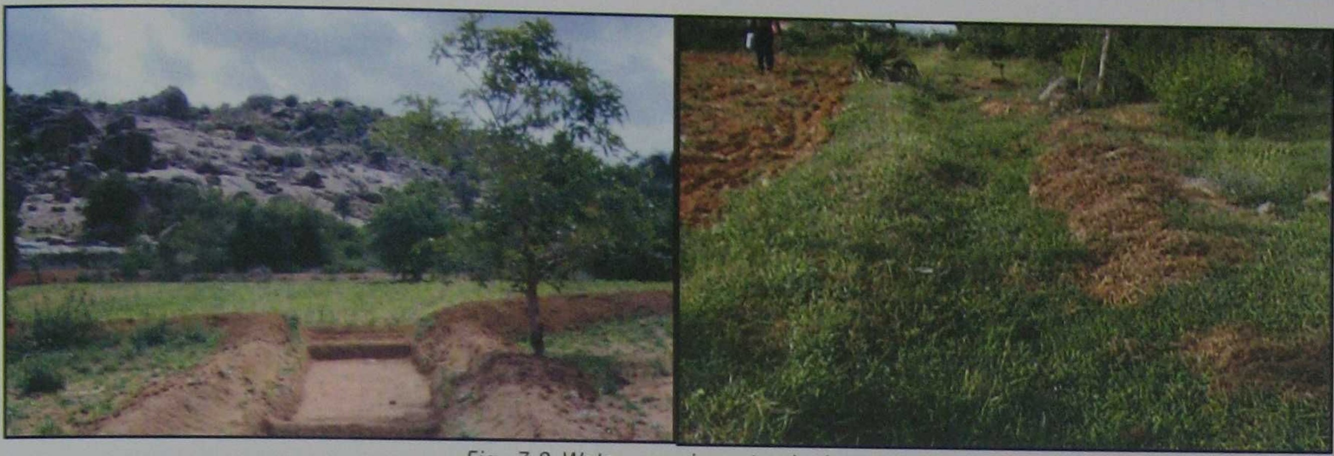


Fig. 7.2 Waterways in watershed area

7.1.4 Gully plugging by gabion structure

Concrete, masonry and brickwork have good resistance to compression but fail easily under tensile loads resulting from settlement. A small settlement of the structure can introduce stresses, which the structure is ill equipped to withstand. Gabion is a wire mesh basket filled with stones. The wire mesh holds the stones together and keeps them in place when the structure is subject to pressure. A gabion is a rigid, bulky mass, not easily shifted by water, and yet a row of linked gabions is fairly rigid and responds well to the terrain. The inherent flexibility of the gabions, the ability to bend without breaking seems to be the primary reasons for their success. These structures are used as checks in the waterways and gullies. The other advantages are:

i) These structures are flexible to soil movement

ii) They are permeable to water but retain soil

iii) The materials are reusable, if structure fails

iv) They are suitable when firm foundation is not available

v) Height of the structure can be raised as and when required

vi) Variable size stones can be used for construction

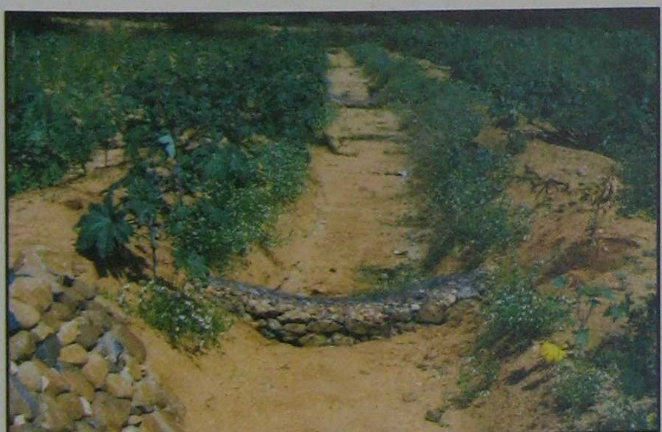
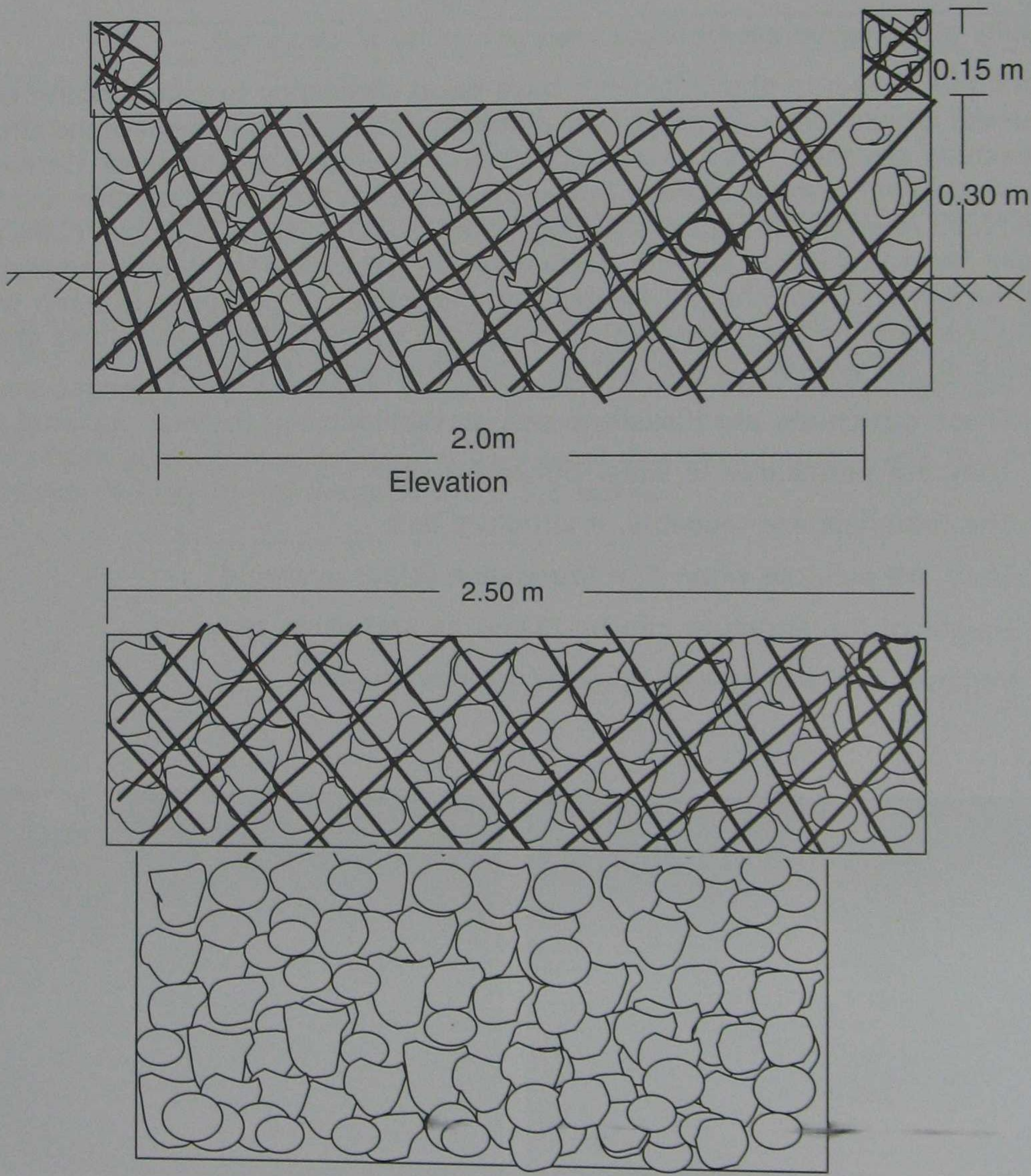


Fig. 7.3 Gabion structure on waterways

Fig. 7.4 Gabion drop structure

Fig. 7.5 Gabion structure in a gully

Fig. 7.6 Cascading gabion structure



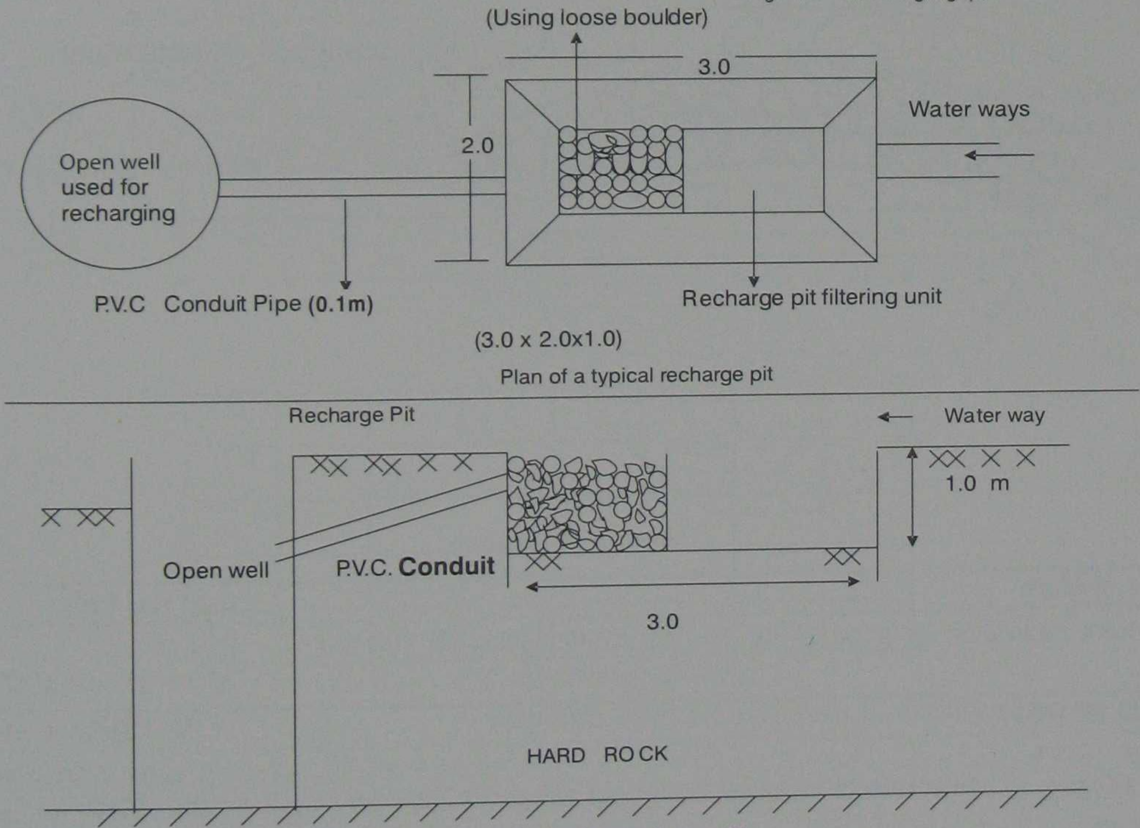
* Diagram not to scale

Cost estimation per m³ of gabion (digging, constructing & shaping)	
G.I wire mesh required for gabion (12 gauge, 2" x 2")	= 6.00 m^2
Cost of wire mesh (16 gauge G.I. wire) Rs 55 /- m^2) + binding wire	= Rs 340.00
Cost of loose boulder. (1.0 m^3)	= Rs 200.00
Cost of earth work (0.3 m^3)	= Rs 10.00
Skilled labour for making gabion (2 man-days)	= Rs 200.00
Total	**= Rs 756/- per m^3 of structure**

7.1.5 Recharging pit

The purpose of the recharging pit constructed in the watershed is to collect and divert runoff water to the defunct well for recharging ground water. The runoff water from the hillock was diverted to the defunct open well (10 m deep) as shown in fig.7.7 through a PVC pipe, of 0.1m diameter. Loose boulders were put in the pit to filter the water before entering the well.

Fig. 7.7 Recharging pit



Recharge of defunct well

Cost of the structure = Rs. 1950/-

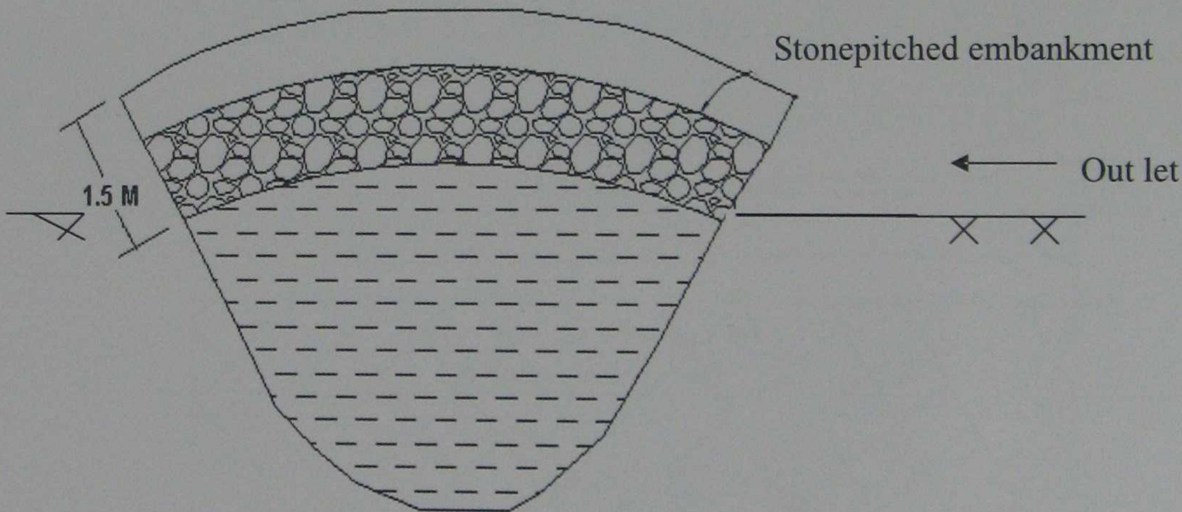
** Diagram not to scale (all dimensions are in meters)*

7.1.6 Percolation pond

Percolation pond store the runoff water for the purpose of recharging ground water. This is constructed across the waterway and is linked to the diversion drain to collect runoff for recharge of ground water and increase the water level in the nearby wells. The soil of the project site is highly permeable and is good to have such structures.

Fig. 7.8 Percolation pond in watershed area

The percolation pond is constructed considering the average runoff potential of the catchment area (3.04 ha). In the last 3 years the structure did not over spill. Hence, about 100 cum/ha of catchment can be taken for the design of percolation pond. Stone pitching was made for stabilizing the bund. The earthen bunds formed at the periphery of the percolation pond was covered with stylo and pongamia grasses.



* Diagram not to scale

Details of work	Cost Rs. (m^3)
Earth work excavation for pond @ Rs 35/- per m^3 (Including lift 100 mts)	250 m^3 250 x 35 = Rs 8750/-
Shaping the embankments (3 man days Rs 50/- man day)	= Rs 150/-
Stone pitching of embankments including outlet (80 m^2 @ Rs 52/- per m^2)	= Rs. 4160
Total cost	= Rs 13060.00/-
Cost per m^3 = Rs 26.42/- say Rs 27.00	

7.1.7 Bio-engineering structure (Sand bag check)

Sand bag structure is a low cost temporary gully control structure made of empty fertilizers / cement bags filled with sand. They are used mostly in upper reaches of small gully having less discharge and having availability of sand in good quantity. The cement bags are filled with sand and piled one above the other in rows in filling the gully. Whenever the sand bags are damaged they are replaced. This structure was stregthened through bio-engineering approach by supporting it with vegetation (*Gliricidia*) on down stream side. In the project area the gliricidia plants planted on either side of the sand bag structure have strengthened the structure figs. 7.9 & 7.10.

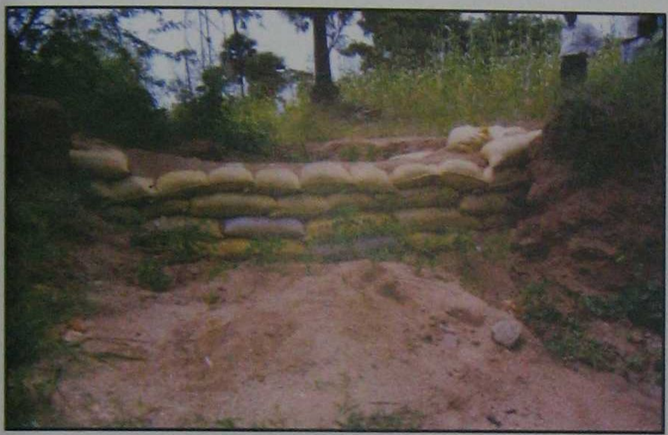


Fig. 7.9 Sand bag check

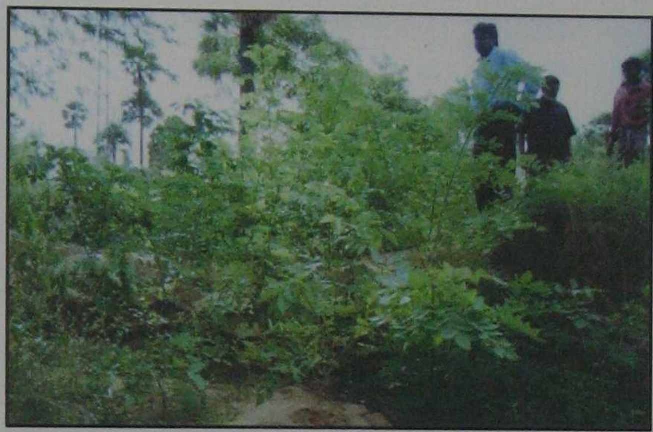
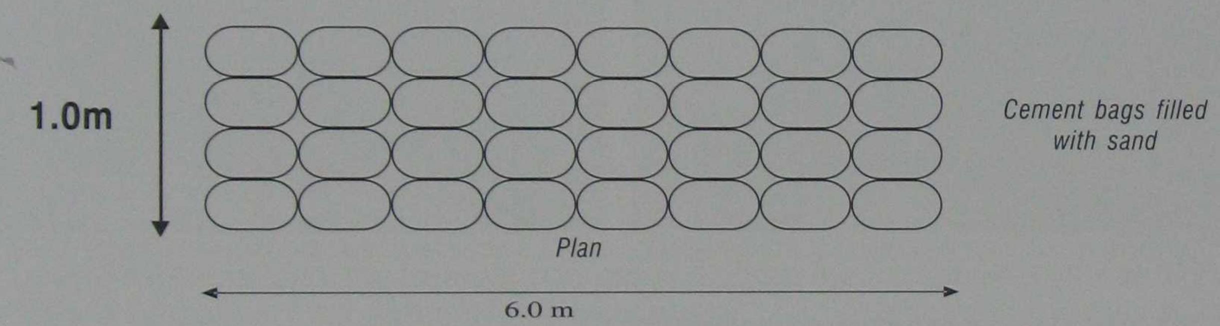
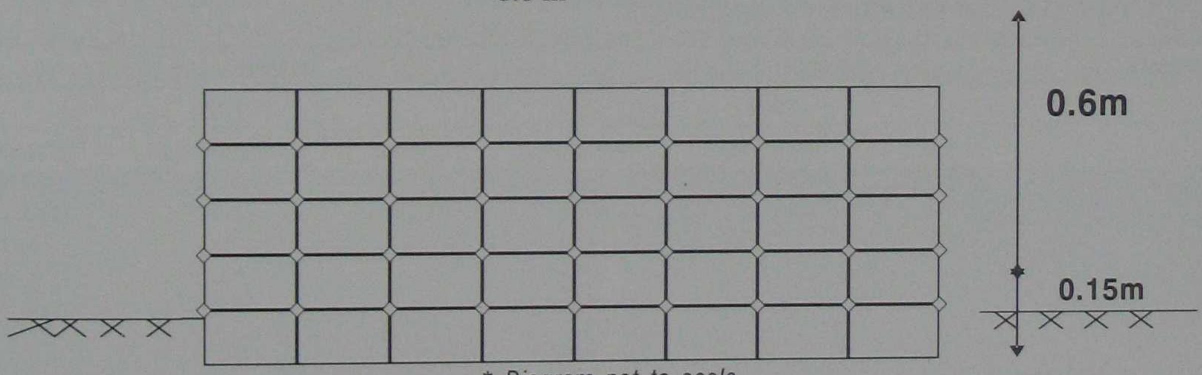


Fig. 7.10 Bio-engineering structure (Sand bag check, strengthened with gliricidia plants)





* Diagram not to scale

Details of work	Cost Rs. (m^3)
Empty cement bags (210 Nos @ Rs 2 each)	420=00
Labour for earth work (1 no)	50=00
Labour for filling sand bags from near by nala and arranging them in piles (4 nos)	200=00
Total cost	**Rs 670=00**
Cost per m^3 = 149 say 150=00	

8.0 Resource Conservation

8.1 Monitoring of runoff and soil loss

The hydrologic gauging stations (3nos.) with H-flumes were erected in the micro watersheds representing three treatments, viz., Control (Un-treated, Treated watershed and Treated Hillock. The H-flumes were designed based on the hydraulic principles (Bos, 1989) and fabricated locally. A Software was developed to calculate the flow using H-flume (Annexure - 1). The analysis of hydrologic data indicates the effectiveness of conservation measures in reducing the resource losses. The treated hillock having a series of depression storages (sunken pits) in the diversion channel bed could reduce the runoff by 90% as compared to untreated watershed (control). The treated agricultural watershed recorded 50% reduction in runoff compared to control. Comparison of different hydrological parameters is presented in table 8.1.

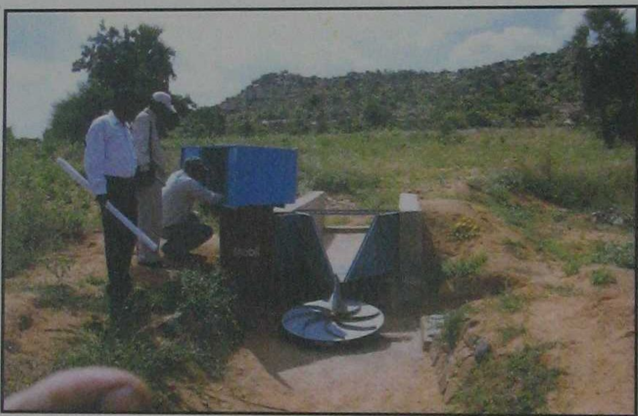


Fig.8.1 Stage level recorder installed near treated hillock

Fig.8.2 Stage level recorder installed in treated arable land

Table 8.1 Hydrological response to treatments

Parameters	Rainfall: 617 mm			Rainfall: 419 mm		
	2003			2004		
	Treated arable land (cultivated area)	Treated non arable land (hillock)	Untreated arable land (control)	Treated arable land (cultivated area)	Treated non arable land (hillock)	Untreated arable land (control)
Runoff events	4	4	11	3	3	8
Runoff producing rainfall (mm)	129	160	329	118	88	226
Runoff of producing rainfall (% total rainfall)	21	26	53	28	21	54
Max. runoff (%runoff producing rainfall)	0.5	1.2	2.1	2.9	1.3	7.0
Peak flow (mm/hr)	0.35	0.43	1.33	0.4	0.42	1.23
Soil loss (suspended load, kg/ha/year)	0.6	2.9	44.0	0.8	4.9	71.5

On an average the runoff producing rainfall is about 53% of total rainfall in untreated area and this got reduced to 21% with treatment of arable land. The expected maximum runoff was found to be 7% and the minimum being 0.5% from the treated area indicating the effectiveness of treatment. Also, the peak flow and soil loss are more in untreated lands.

8.2 Effect of structures on soil resource conservation

The gabion and loose boulder structures were constructed in series for stabilizing the grade of channels, waterways and diversion drains. In due course it was observed that the displaced from catchment area are deposited upstream of these structures (Figs. 8.3 & 8.4). This process was measured by putting graduated wooden pegs on upstream side of structure and measuring the depth of deposited soil. It was also observed that the sand casting in the channels was reduced compared to earlier period indicating the reduction of soil erosion. It was found that four tons of soil has been conserved by gabion checks and check dams.

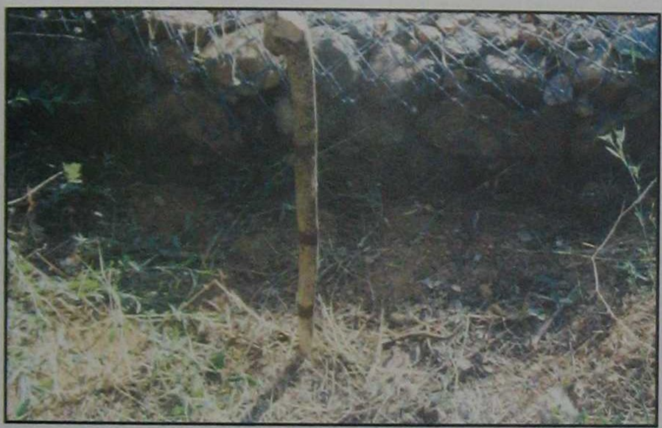


Fig.8.3 Graduated wooden peg at upstream side of gabion structure

Fig.8.4 Deposited soil measure using graduated wooden peg

During PRA exercise, the farmers complained about the formation of rills and gullies at different places in their fields in the watershed. The project team identified all the spots where rilling and gully formation were prominent during ground truth collection. Accordingly, diversion drains, waterways, gabions and earthen checks etc. were planned

Fig.8.5 Farmer showing land affected by gully erosion

Fig.8.6 Reclamation of gully by constructing percolation pond in upstream of gully

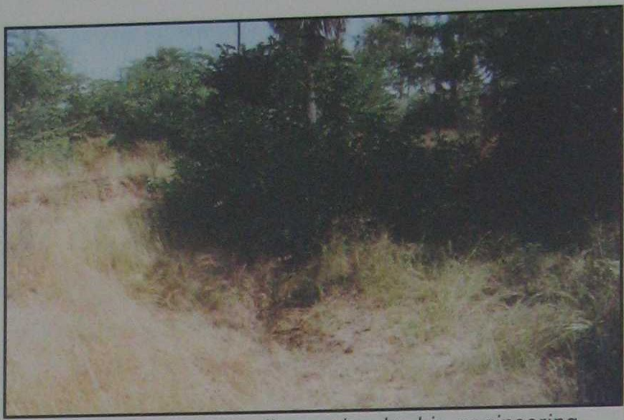


Fig.8.7 Control of gully erosion by bio-engineering structure (sand bag check with gliricidia on sides)

Fig.8.8 Control of gully by construction of diversion channel

to divert the runoff. It has been observed that an area of 15 ha has been saved from rill and gully erosion after construction of waterway, diversion channel, etc. The area subjected to rill and gully erosion is now under cultivation. (Figs. 8.5, 8.6, 8.7 & 8.8).

8.3 Participatory ground water monitoring

Ground water level monitoring was started since March 2003 and the observations were recorded on weekly basis every Saturday. Nine different sites (bore wells) were identified for ground water level monitoring. Five wells were used for irrigation and the remaining four were out of use. A typical well hydrograph of a bore well indicate an increase in water level by about 1.0 m in spite of very low rainfall in year 2004 (Figs. 8.9 & 8.10). This reflects the impact of soil and water conservation measures, which would have been many folds with receipt of normal rainfall over years.

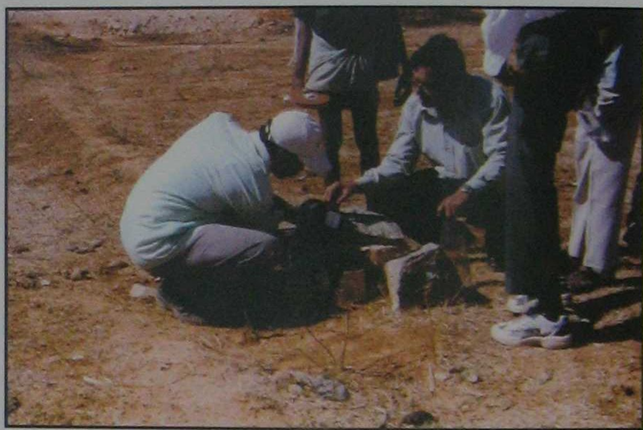


Fig.8.9 Para worder monitoring ground water level

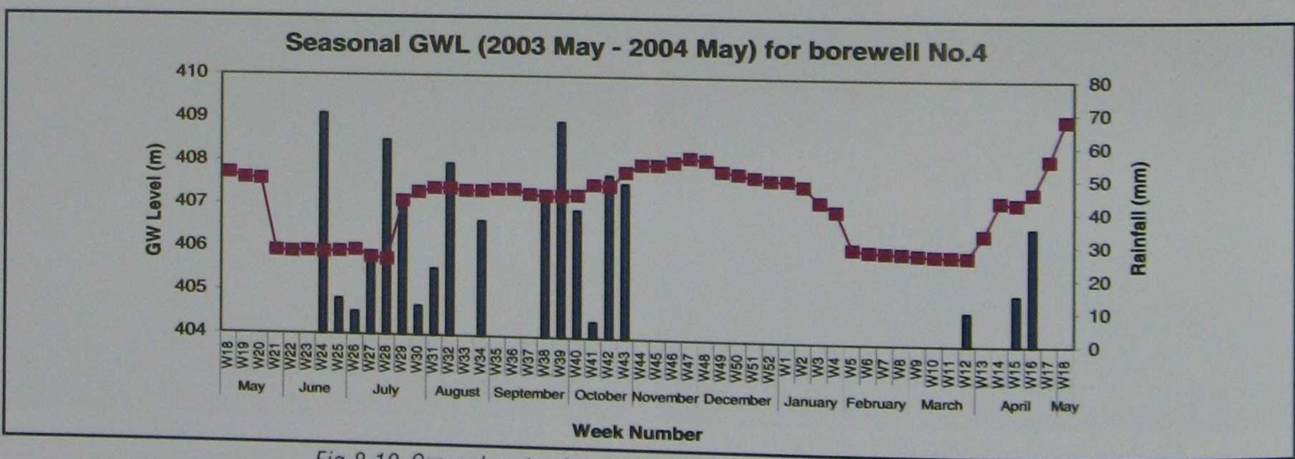


Fig.8.10 Ground water level (GWL) fluctuations in a borewell

9.0 Crop Production

The Nalgonda district lies in the Southern part of Telangana region of Andhra Pradesh between 16^0 25' and 17^0 50' of the Northern latitude and 78^0 40' and 80^0 5' of Eastern longitude. There are 59 mandals in the district. The average rainfall of the district is 690 mm, while Chintapally mandal in which S.S. Pally micro-watershed is located receives only 510 mm. This area is considered as rain shadow region. Coefficient of variation is very high (50%). About 70% of the total rainfall is received during South-West monsoon period.

The area is highly prone to drought; agricultural drought frequency is as high as 100% while hydrological and meteorological drought frequency are 57% and 43%, respectively. This indicates that this mandal is highly vulnerable to agricultural drought compared to hydrological and meteorological drought. Only 11% area is under irrigation through borewells, tanks, etc. compared to the district average of 36%. There are no big forests of importance in the district, they are mostly thorny, scrub vegetation. The soils of the district are mostly red (91%) and rest is black. Among the red soil, 47% is *dubba* (loamy sand) with very low water holding capacity and the rest is chalka (44%). Principal crops of the district are sorghum, bajra, redgram and castor which are tolerant to drought. Paddy is mostly grown under irrigated condition.

9.1 Cropping pattern

About half of the area SS Pally of watershed is under cultivation and the remaining 50% is covered by hillocks, gullies/waterways, habitation, un-cultivated fallow, etc. Castor ranks first in area (57 acres) followed by sorghum (30 acres), cotton (28.0 acres) and paddy (4.0 acres). The production programme focused on introduction of improved varieties of sorghum and castor.

Improved variety of sorghum (SPV-462) was distributed among farmers during kharif 2002-04 on large scale as it showed good performance. Redgram (drought resistant variety: Maruthi) was distributed to the farmers to promote intercropping with sorghum. Three kilograms of sorghum, one kilogram of redgram, 18 kilograms of DAP and 22 kilograms of Urea were given to each farmer for one acre of land for the purpose of comparison with local variety. The grain and straw was liked by the farmers.

9.2 Crop performance (Sorghum: SPV-462)

The rainfall behaviour was different during 3 years study period and growth of sorghum also performed differently (Table 9.1). Crop performed well in year 2002 (Figs 9.1 & 9.2), although the total amount of rainfall was less but distribution was better while it was a classical drought year all over India. Normal yields were obtained in year 2003 but crop suffered with grain mould due to rain at the time of harvest. Year 2004 is considered the most severe drought year, when compared to 2002 as both local and SPV-462 failed. Crop suffered with heavy infestation of red hairy caterpillar at the initial stage and later by dryspell for one month. Sorghum couldn't be sown during June due to lack of sufficient rains and was shows only in July. August was total dry and rains were received only in September. Castor was found to be more stable crop than sorghum and there was greater demand for the seed of castor (Var: Kranti). Farmers paid for the cost of seed of castor and crop performance was found better as it is deep rooted and drought tolerant.

Table 9.1 Performance of improved sorghum variety

Variety	Kharif 2002	Kharif 2003	Kharif 2004
SPV-462	1.2 t/ha	1.3 t/ha	Sorghum failed (both local and improved)
Local	0.95 t/ha	1.0 t/ha	
Percent increase in yield of SPV-462 over local variety	26 %	30 %	
Rainfall during season (mm)	261	369	184
Number of rainy days	17	25	16
Remark	Low rainfall but well distributed	Normal	Delayed on-set monsoon, instead of June, setting was in July. Prolonged dry spell of 30 days (August to September 2004)

Fig.9.1 Local variety of sorghum

Fig.9.2 Sorghum (var: SPV-462)

9.3 Soil amendment (Application of gypsum)

The soils of a farmer's field which had a pH of 8.0 was taken up for the amelioration study. The exchangeable Na content of these soil was 1.0 cmol kg^{-1} soil. In order to lower the pH to normal range (around 7.0) as well as to supply 'S' for castor crop, gypsum was preferred and applied in the field at the rate of 1.87 t/acre and a control plot without any gypsum was maintained. The material was uniformly incorporated with a country plough after receipt of monsoon rain. The soil was allowed to settle for a brief period before sowing of crop. The cultivation of Castor (*Ricinus communis* Linn) was taken up in treated and control plots. The gypsum treated plot performed better in terms of plant height and flower initiation (Figs. 9.3 & 9.4). At the flowering stage, the soils were sampled and analyzed for the following parameters viz. pH, EC and exchangeable Na. The results of the soil analysis before sowing and at flowering stage are presented in table 9.2.

Table 9.2 Changes in soil properties before and after application of gypsum

Soil property	Before sowing	During flowering
pH	8.0	7.4
EC (dSm^{-1})	NA	0.16
Exch. Na ($cmol^{-1}$ kg^{-1} soil)	1.00	0.44

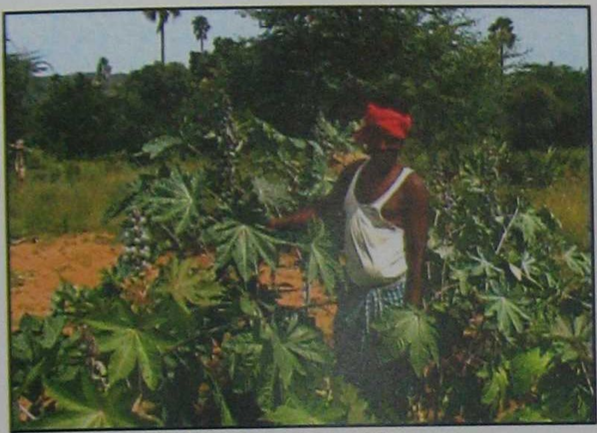


Fig.9.3 Plot treated with gypsum

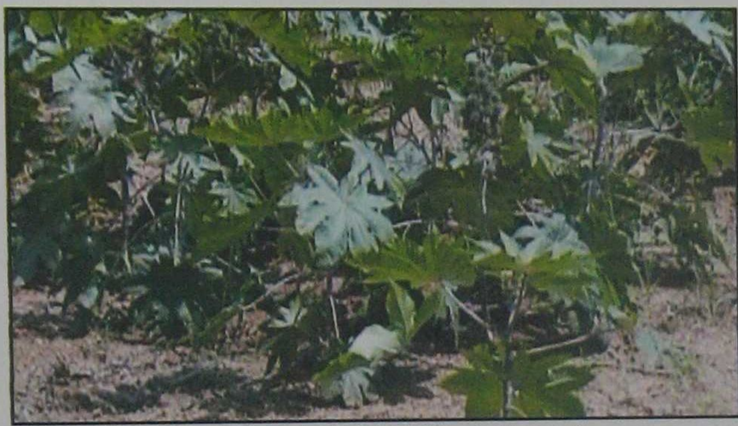


Fig.9.4 control plot (without gypsum)

9.4 Livelihoods generation

Crop production is highly risky in this area and one of the important sources of alternate livelihood is tapping of juice of Palmayra palm (*Borassus flabellifer*) for production of local liquor (*toddy*) and sheep and goat rearing (Figs. 9.5 ,9.6 & 9.7). Tappers and sheep rearers are better off compared to farming community.

Fig.9.5 A tapper climbing the palmya palm

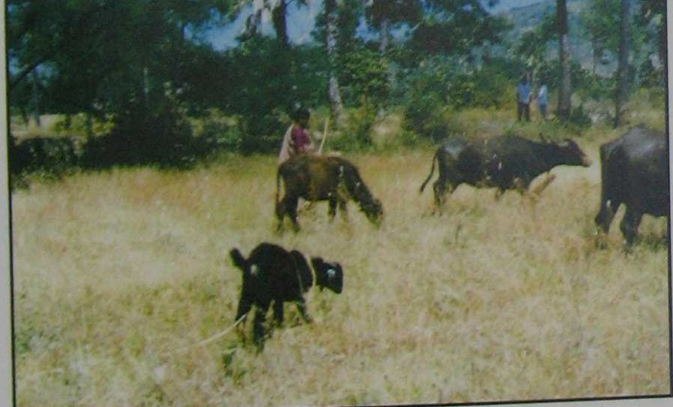


Fig.9.6 Women worker rearing livestock

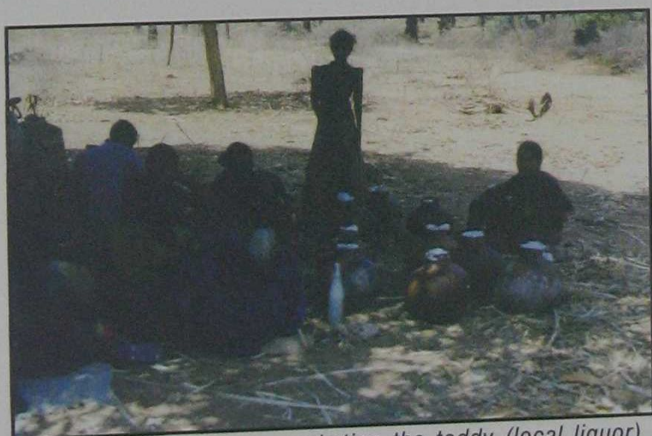


Fig.9.7 Women group marketing the toddy (local liquor)

10.0 Alternate Land Use

10.1 Greencapping of bunds / waterways

All the bunds and waterways were green capped using Sabi grass (*Urochloa mosambicensis*), Guinea grass (*Panicum maximum*), Anjan (*Cenchrus ciliaris*) and Stylo (*Stylosanthes hamata*). The seeds were mixed with sand and sown in furrows opened by using tooth harrow and later covered by running local thorny bush (Figs. 10.1, 10.2 & 10.3). Stylo legume performed better than other grasses (Fig. 10.4). This indicates stylo is more drought tolerant and hardy than grass, which might be due to its deep root system. Grasses with shallow root system didn't perform well in shallow alfisols because of poor rainfall in the past three years. On either side of the bunds gliricidia, pongamia and cassia were planted. The farmers preferred gliricidia compared to pongamia and cassia.

Fig.10.1 The grass seeds mixed with sand

Fig.10.2 Furrows opened using tooth harrow for placing grass seeds

Fig.10.3 Covering of seed by running thorny bush

Fig.10.4 Green capping of bunds with stylo

10.2 Plantation programme

The area is famous for sweet orange plantation and farmers were keen to plant sweet orange in the micro-watershed. Supply of seedlings was arranged with Tirupati campus of ANGRAU but programme couldn't take off due to failure of monsoon and

Fig.10.5 Marking of the pit for plantation

Fig.10.6 Removal of soil layer from pit

lack of groundwater because of drought for the past three years. Farmers were apprehensive about the survival of plants as there is acute shortage of even drinking water. To keep the interest alive and to support all the families in the village, planting of one tree of their choice near their residence was promoted. As an incentive, one bamboo tree guard was provided because the open space near their residence is prone to grazing / browsing by livestock. All the families of the S.S. Pally village were very happy to receive a fruit plant of their choice. Before taking-up plantation, a small training programme was organised to create awareness about site selection, digging, filling, planting and plant care. Men and women were trained about the making of pit (0.45 m x 0.45 m x 0.45 m) and micro-site improvement. Before digging, area of the pit was marked on the ground (Fig. 10.5). The pits were dug to a depth 0.45 m (Fig. 10.6) and care was taken to separate the soil layer wise (0-15 cm, 15-30 cm & 30-45 cm) and was kept separately (Fig. 10.6). Later, the topsoil (0-15 cm) was put at the bottom of the pit after removing stones, if any. The second layer (15-30cm) was mixed with two basket of FYM and one basket of tank silt, 100 gm of DAP and 5 gm of Thimmet granules. The mixture was filled to a height of 10 cm above the ground. After planting, the bottom soil was used for making saucer round the plant (Fig. 10.7) by leaving an opening for catching runoff.

Fig.10.7 Saucer - a micro catchment for the plant

Planting without protection is going to be waste; therefore, simple low cost bamboo tree guards were got fabricated. The local artisans were given specifications to make bamboo tree guard, which is about ten times cheaper than iron make costing about Rs. 1000/- each. CRIDA staff explained the procedure of netting bamboo tree guard to local artisans. It is observed that, three tree guards can be prepared in a day by two persons and raw material costs Rs. 150/-. Fabricators get a margin of Rs. 150/-, which works out to be Rs. 75/- per day per person, which is better than the prevailing

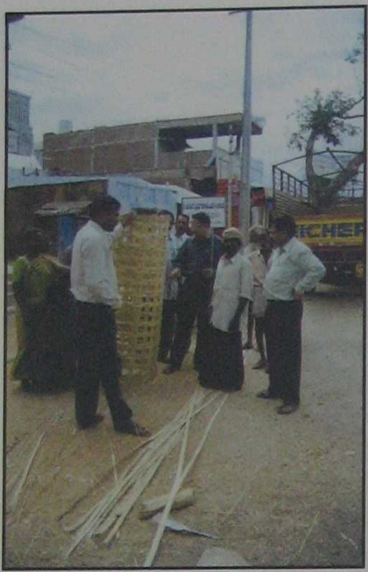


Fig.10.8 Discussion with local artisans (bamboo netters)

wage of Rs. 50/- per day per person (Fig. 10.8). This helped in improving the skill of the artisan as well as generated employment in the rural area. Bamboo tree guard (Fig. 10.9) was preferred over iron as it is not only costly but also prone to theft. Bitumen was applied at the bottom to improve the life of bamboo and to protect from termite. All the households received one plant each of their choice; most families preferred acid lime and their survival is 100 percent (Figs. 10.10 & 10.11). The following table gives the distribution of plants.

Fig.10.9 Bamboo tree guard

Fig.10.10 Fruit sapling distribution

Fig.10.11 Tree planting and bamboo tree guard

Table 10.1 Distribution of sapling to each household in the village

S.No	Plant and variety	No
1	Acid lime (Balaji)	47
2	Sapota (Kalipatti)	34
3	Mango(Benishan)	32
4	Curry leaf (Suhasini)	28
	Total	**141**

10.3 Avenue plantation

To improve the aesthetic value, avenue plantation was carried out. The following plants were planted on either side of the road during July, 2004 (Table 10.2). The plants were protected by providing fence of local material and also bamboo tree guards. Two times supplemental watering was done during prolonged dry spells (Fig. 10.12). Gulmohar was found to be fast growing followed by copper pod tree and exceeded the height

Fig.10.12 Watering of avenue plantation

Fig.10.13 Gulmohar exceeded the height of tree guard within six months

of tree guards (Fig. 10.13). All the plants recorded more than 95% survival. Mulching was promoted for all the avenue and fruit plants using paddy husk (5 cm thickness) in the basin.

Table-10.2 Choice of species for avenue plantation

S. No	Tree species	No. of Saplings (Right side of the road)	No. of Saplings (Left side of the road)	Total Saplings
1	Jamun (*Syzygium cuminii*)	16	7	23
2	Gulmohar (*Delonix regia*)	24	13	37
3	Copper pod tree (*Peltophorum ferrugineum*)	15	12	27
4	Fountain or Tulip tree (*Spathodea Campanulata*)	17	5	22
5	Seema Tangedu (*Cassia siamea*)	24	10	34
6	Sissoo (*Delbargia sissoo*)	13	4	17
			Total	**160**

11.0 Visitors to the Watershed

Besides frequent visits by farmers, state officials, NGOs, students and trainees many national and international dignitaries also visited the watershed and gave useful suggestions (Table 11.1). Dr. B.K. James, Principal Scientist, WTCER (ICAR), Bhubaneswar visited the watershed in February 2003 and reviewed the progress and programme. He appreciated the concept of creating awareness on resource losses through demonstration of portable rainfall simulator as an action learning tool. For quantifying the soil loss he suggested to measure the deposition of soil upstream of hydrologic structures by putting wooden pegs with markings on them for measuring the levels of soil deposited. He also suggested to monitor the ground water level in the wells. Accordingly the pegs were put upstream of the structures (Figs 8.3 & 8.4) and water level indicator was used to measure the water level fluctuations (Figs 8.9 & 8.10) by a farmer (unemployed youth).

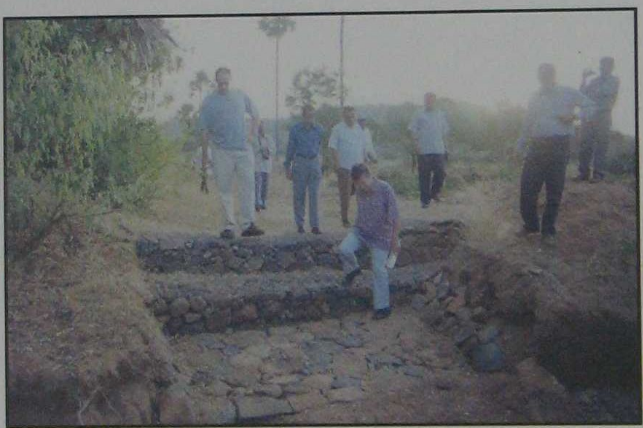


Fig.11.1 Dr. Margaret Quin, DFID, UK inspecting the gabion

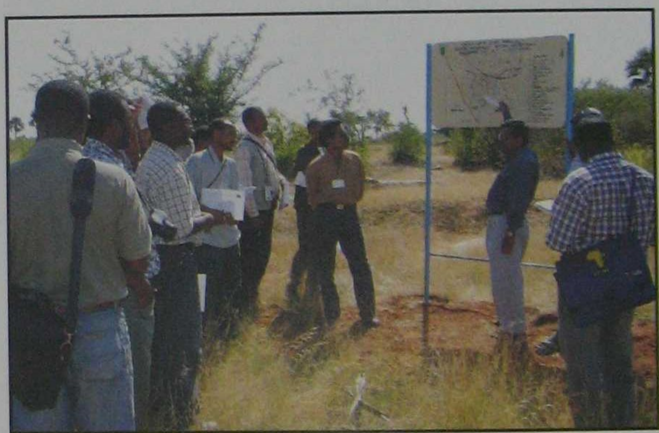


Fig.11.2 Dr. P.K. Mishra explaining to Ehiopian team

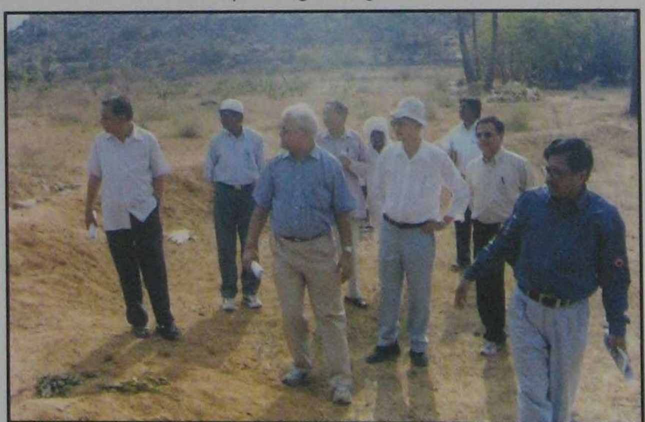


Fig.11.3 Dr. T.C. Ti from FAO, Dr. Gyanchander Mehta, Member, Institute Management Committee visiting the watershed

Fig.11.4 Australian team visiting the project areas

Table 11.1 List of visitors are visited in the watershed village

Sl.No.	Date	Visitor
1	21st November 2002	Dr. P.C. Senapati, Chief Scientist, AICRPDA, Phulbani
2	1st December 2002	Dr. Margaret Quin, UK (DFID team)
3	7th February 2003	Dr. B.K. James, Principal Scientist, WTCER (ICAR), Bhubaneshwar
3	24th February 2003	Dr. T.C. Ti from FAO, Dr. Gyanchander Mehata, Member Institute Management Committee
4	1st May 2003	Watershed committee members form Jharkhand State, under KVK training programme
5	21st May 2003	Forest Department Trainees by TOT, CRIDA
6	22nd May 2003	KVK trainees farmers from Nalgonda District
7	19th June 2003	Women farmers under CRIDA-UNDP programme
8	9th August 2003	W.D.T. trainees by TOT, CRIDA
9	6th September 2003	Dr. B.R.M. Rao, PI and his team from NRSA
10	8th December 2003	Enyew Adgo, Director, Natural Resource Management Research, Amhara Regional Agricultural Research Institute, ARARI, Bahir Dar, Ethiopia
11	30th August, 2004	Australian team
12	2nd November, 2004	Ethopian team

12.0 Project Impact

The local farmers/villagers have taken keen interest in the project activities even though drought prevailed all through the project period. The visible impacts include (i) the reclamation of gullies, (ii) restoration of land from rillings (iii) reduction of runoff and soil loss, (iv) improvement in ground water level (v) introduction of sorghum variety SPV-462 and Castor (*Var: Kranthi*) and improvement in productivity of sorghum by 25 to 30% (vi) Creation of awareness on cropping and resource conservation activities (v) participatory monitoring etc. The villagers wish that the CRIDA team should stay and guide them over a long period and extend the programme to larger area.

Key learning

- Integration of remote sensing & GIS is very much useful for priority setting and preparing the action plan at macro-scale. But, with the advancement of technology the high resolution data will be used for planning and implementation of watershed activities at micro-scale (500 ha and less).
- Socio-economic criteria may be integrated with bio-physical parameters for prioritization of critical areas for priortization and development.
- The demonstration of action learning tool like portable twin plot rainfall simulator helped in creating better understanding of resource conservation by land management amongst the villagers.
- Exposure visit to nearby watershed and research farm helped in motivating farmers on watershed programme planning and implementation.
- As an entry point activities avenue plantation and household plantation may be taken up.
- Topographic survey is a must before initiation of the programme at a micro level and gives sound footing for integrating technical plan with PRA exercise for developing joint action plan. During the survey, minor details like survey number, soil, vegetation and land uses may be collected for making the action plan more useful to the beneficiaries. Survey is needed as the SOI (Survey of India) map does not give all the details and the contours are drawn at wider intervals (20 m).
- Emphasis should be given to stop rill formations through appropriate soil and water conservation measures.
- Interventions like application of gypsum in farmer's field (with alkaline soil reaction) could amend the soil and increase the yield. This type of problem oriented intervention builds the confidence and satisfaction of the farmers.

- The gabion structures as checks in gully and waterways were appreciated by the farmers and developmental agencies as well.
- Considering the high level of spatial variation in rainfall at micro level, a rain guage should invariable be fixed in the watershed area to record the actual rainfall.
- The runoff producing rainfall in untreated area is found to be 53% of total rainfall, which is reduced to 21% in case of treated area.
- For design of overflow structures in the cultivated field the rainfall intensity of 50 mm/hr may be sufficient. 100 m^3 of storage from one hectare of catchment can be considered for design of water harvesting structures.
- To make the plantation programme successful, low cost bamboo tree guards may be introduced besides supplemental irrigation during dry period in the first year of the programme.
- From the land use survey it was clear that the palmyra plants are drought resistant and more useful to this area and the village community. Traditionally neem is grown in this area and is liked by the farmers for its medicinal and timber values. Pongamia is grown along the waterways and potential exists to use the plant leaf as green manure and bio-diesel from seed.
- The villagers should be involved from the beginning for participatory monitoring of watershed activities. Participatory hydrological monitoring of ground water increases the awareness of the farming community on resource depletion or improvement.
- The gauging device for measuring runoff and soil loss may be invariably installed at some hot spots for creating awareness on resource losses and recording the effectiveness of conservation measures as a part of monitoring and evaluation programme.
- Farmers are always interested to have good quality seed and planting material to increase the present yield level, even they are prepared to pay the cost of seed and planting material.
- The NRM based project should continue for more than 5 years for capturing the effects of rainfall variabiality and strengthening local capacity and withdrawal mechanism.

13.0 Conclusions

In this project a comprehensive methodology was developed for prioritizing the critical areas on a regional scale for taking up developmental activities on watershed basis. Remote sensing and GIS was found useful in developing a broad action plan at regional level. However, to develop an action plan for a micro-watershed detailed topographic survey is needed as the SOI (Survey of India) map does not provide information with higher resolution. The preparation of action plan on the basis of available resource and thematic maps is quite effective and useful. The farmers respond well to the watershed programme and cooperate in making the programme successful if their involvement is planned from the beginning. Action learning exercise like demonstration of portable rainfall simulator was helpful in convincing the villagers on conservation measures by physically witnessing the runoff and soil loss. The introduction of simple conservation measures like across the slope cultivation is now followed by most of the farmers for soil and water conservation. The farmers took lot of interest in locating their fields in the cadastral map and listing out the interventions during PRA exercise. It was difficult to get physical contribution from the farmers in terms of cash, but they agreed for soil conservation measures that took away a part of their land. Most of the farmers are resource poor and have small holdings. The introduction of gauging of rainfall (by rain gauge), runoff and soil loss by H-Flume with stage level recorder, Coshocton wheel) and ground water level (by water level indicator) helped the farmers in understanding the hydrology of the area as they were involved in measuring the rainfall, maintenance of H-Flume and measurement of ground water levels in different bore wells located in the watershed area. The ground water level monitoring shows a slight increasing trend in ground water level despite drought situation. The formation of gullies and rills has been arrested and the displaced soils have been deposited behind the conservation structures. Bio-engineering measures like sand bag check along with *Gliricidia* on the sides are found to be effective and liked by the farmers. All the villagers took interest in roadside avenue plantation and planted trees of their choice in their houses. Now all these plants are showing good growth and high survival because of personal care taken by the villagers. Farmer's have accepted the sorghum (SPV-462) variety, which was introduced during project intervention. Due to prolonged dryspell and less runoff producing rainfall, the impact of the programme was moderate. Analysis of rainfall and runoff events and hydrological gauging should continue for at least a decade for generating data for the design of hydraulic structures. Such projects should continue for at least 5 years to capture the effect of variations in rainfall.

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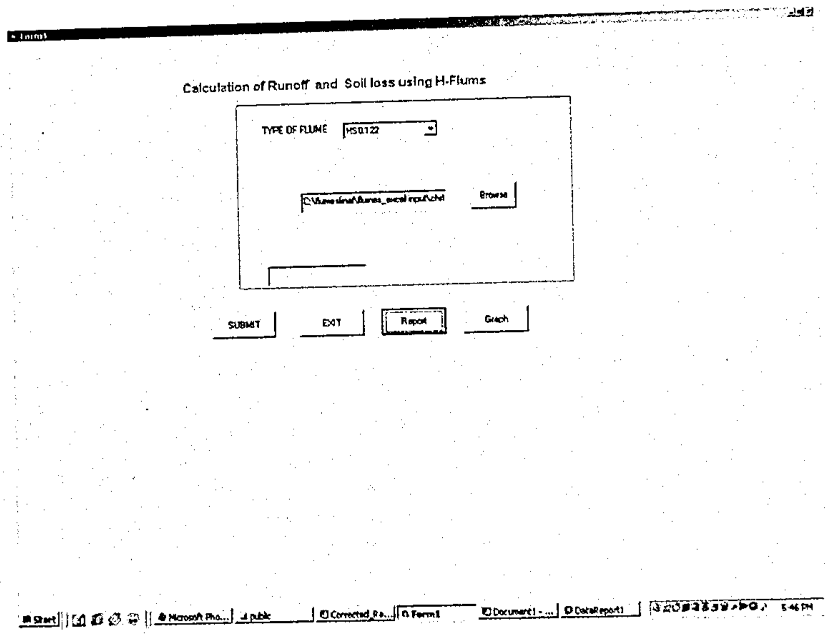
Flow calculation software for H-Flumes

A software was developed in Visual Basic for calculating soil loss, runoff and peak flow etc. using H-Flume and Coshocton wheel runoff sampler. A sample of input data and software output is presented below.



	A	B
1	Date	15/07/2003
2	Place	SSPALLY
3	Treatementname	Control
4	FlumeType	2ft(0.61 m) Hflume
5	Gearratio	2
6	TimeFactor	0:28
7	Starting time of Hydograph(Hrs)	12:20
8	Watershed Area(ha)	3.5
9	Rainfall(mm)	36
10	Sediment Loss(Gr/l)	1.62
11	Ttime(No of small Div. In X - axis)	Depth of water in Flume(No of Small division In Y-axis)
12	0	0
13	1.5	49
14	2	15
15	5	0

Same output file of the software module for the above input file

DataReport1

Zoom 100%

Calculation of Runoff & Soil loss using H-Flums

Date	:	07/15/2003
Place	:	SSPALLY
Treatment Name	:	Control
Flume Type	:	2ft(0.61 m) Hflume
Gear Ratio	:	2
Time Factor	:	00:28
Starting Time of Hydrograph (Hrs)	:	12:20
Watershed Area (ha)	:	3.5
Rain Fall (mm)	:	36
Sediment Loss (Gr/l)	:	1.6200

Date	Time (Hrs)	Time (min.)	Time Intervals	Depth of Water (m)	Flow Rate (cum)	Flow Rate (mm/hr)	Run off (Cum)	Cum.Runoff(Cum)	Cum.Runoff(mm)
15.07.03	12:20	0	0	0	0	0	0	0	0
15.07.03	13:02	42	2520	0.245	0.011995	1.23377142857143	15.1137	15.1137	0.43182
15.07.03	13:58	56	840	0.075	0.000811	8.34171428571429E-02	5.37852	20.49222	0.585492
15.07.03	16:18	140	5040	0	0	0	2.04372	22.53594	0.643884

Total Flow/Runoff (cum)	:	22.53594
Peak Flow (cumec)	:	0.011895
Peak Flow (mm/hr)	:	1.23377142857143
Total Runoff (mm)	:	0.643884
Percent Run off	:	1.78856666666667
Total Soil Loss (Kg)	:	36.5082228
Soil Loss (t/ha)	:	0.0104309208

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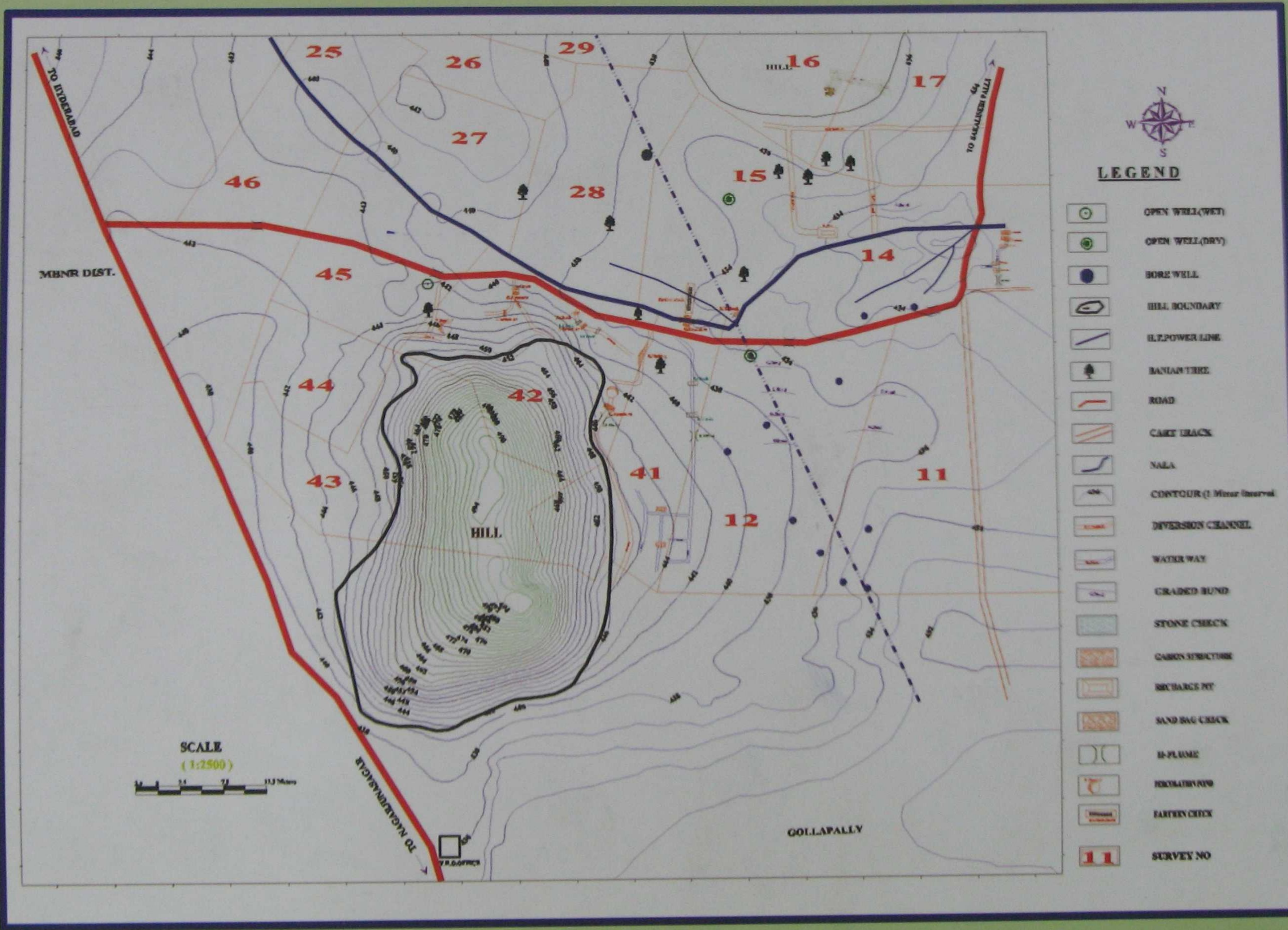

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CART TRACK
NALA
DIVERSION CHANNEL
WATER WAY
GRADED BUND
STONE CHECK
SAND BAG CHECK
H-FLUME
EARTHEN CHECK
SURVEY NO
TO HYDERABAD
MBNR DIST.
TO NAGARJUNASAGAR
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