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Research Article

LAND RESOURCE INVENTORY FOR DEVELOPMENT OF SUSTAINABLE AGRICULTURAL LAND USE PLANS USING GEOSPATIAL TECHNIQUES: A CASE STUDY OF SANTIKALLUR NORTH-5 MICRO-WATERSHED

RAJESH N.L.*[1], HEMANJALI A.M.[2], NAGABHUSHANA[3], CHAITRA[4], RAJESH V.[4]

[1]Department of Soil Science and Agricultural Chemistry, Agriculture College, University of Agricultural Sciences, Raichur, 584104, Karnataka, India
[2]Department of Environmental Science, Bangalore University, Bengaluru, 560056, Karnataka, India
[3]Department of Geography, Bangalore University, Bengaluru, 560056, Karnataka, India
[4]RS&GIS lab, The World Bank funded Sujala Watershed Development Project, University of Agricultural Sciences, Raichur, 584104, Karnataka, India
*Corresponding Author: Email - rajesh.neralikere@gmail.com

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Abstract: Lingasugur taluk, Raichur district, Karnataka, India was carried out at 1:8000 scale for characterization and classification of soils, and to derive sustainable land use plan based on the limitations observed in land capability and crop suitability. Soil mapping units were delineated using cadastral map overlaid on IRS-P6 LISS IV merged Cartosat-1 satellite imagery. Land morphological observations and soil survey was carried out and identified five soil series further divided into five soil-phases. The soils were developed on very gently to gently slope. The soil profiles were moderately deep (50-75 cm) to deep (100-150 cm), moderately well drained, slight to moderately calcareous, brown (7.5YR 5/3) to dark gray (10YR 3/1) in color, with sub angular blocky structures and strongly alkaline in reaction (8.02-8.72). Soil texture was sandy clay to clay. The silt has significantly moderate positive association ($p<0.05$) with clay. Sand has significantly moderate negative association with clay ($p<0.05$) and significantly strong negative association with silt ($p<0.01$). Soil available nitrogen (85 to 250.75 kg ha^{-1}) was low and it has significantly strong positive correlation with SOC ($p<0.01$). The available phosphorus was low to medium in range (20.62 to 53.80 kg ha^{-1}) and because of low mobility of available P, it was negatively correlated with Zn ($p<0.01$). ESP has significantly strong positive association with Na ($p<0.01$), and it was significantly strong negative association with clay ($p<0.01$). Land capability sub classes in the study area were IIIes with limitations of soil erosion, texture, soil drainage, soil fertility and topography. The land was highly suitable (S1) for sorghum, bengalgram, custard apple and amla and moderately suitable (S2) for cotton, redgram, bajra and guava with limitations of rooting and topography. Further, soil-phase unit wise crop plan with suitable interventions for field and horticulture crops were developed.

Keywords: *Land resource inventory, Land capability, Crop suitability, Sustainable crop plan, Geospatial techniques*

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Introduction

A detailed survey for mapping land units at cadastral level (1:8000 scale), and to collect descriptive data on land attributes and its resources is required to assess the viability of land for alternative uses. The Land Resources Inventory (LRI) provides information on the morphological and physicochemical features of soils, as well as their issues and potentials for best exploitation under various agro-climatic situations [1]. It generates larger-scale maps of the selected site, showing the extent and distribution of distinct soil groups. Village development, on the other hand, is expected to involve more than just soil and water management. It should be a holistic approach that focuses on human resource development, pasture development, agriculture development, livestock management, and rural energy management in order to improve rural livelihoods. It should seek to develop all human resources in existing nature in a single ecosystem [2].

The purpose of this article is to better understand how land resource data can be integrated with watershed development programmes for optimum utilization. For intensive agriculture, watershed-based assessment of land resources is critical for land use planning and long-term sustainability. The key to making the right selection at the right time for the correct agro-technology transfer in the farmer's field is to provide reliable and accurate information on land resources and sustainable crop plan.

Materials and Methods

Santikallur North-5 micro-watershed is located in Lingasugur taluk of Raichur district lies in the north-eastern plains of Karnataka and falls under semiarid tract of the state. The total geographical area of the village is 330.77ha. It is situated between16º05' N-76º29' E and 16º05' N-7631' E, with a mean sea level (MSL) of 495-508.6 m [Fig-1]. The lithology with granite and gneiss show significant variations in their texture, colour, mineral assemblage and degree of weathering and these variations are reflected in the soil types identified in the area. Only a few small tanks exist in the micro-watershed, and they are unable to store the water that runs during the rainy season. This has a significant impact on groundwater recharge. Total annual rainfall of 307mm of the total rainfall, maximum of 520 mm is received during the south–west monsoon period from June to September. Mean maximum and minimum temperatures are 40.2°C and 10°C, respectively. The average Potential Evapo-Transpiration (PET) is 141 mm and varies from a low of 81 mm in December to 199 mm in the month of May. Important crops grown are Sorghum, cotton, Redgram, Bengalgram Bajra, Amla, Custard apple, Guava natural vegetation is sparse, comprising few tree species, shrubs and herbs.

The detailed survey (1:8000 scale) of the entire micro-watershed was carried out in the year 2017, using cadastral map [Fig-2] and IRS LISS-IV merged Cartosat-1 imagery (2.5 m spatial resolution) through rapid traversing to cover up the soils at varying physiographic position. Based on the recorded observations, such as soil depth, amount and nature of gravel, depth of occurrence of gravel layer and nature of substratum present below soil and horizon sequence characteristics of the soils were grouped for classification of different series in the area [3]. Further, soil series were divided into soil phases based on the surface characteristics with respect to soil texture, slope, erosion and gravelliness.

The classification of soil series was made as per soil taxonomy. Five soil series were identified and further mapped into five soil-phase units and their area distribution and description were mapped [Table-1]. Soil samples were collected from representative pedons and analyzed for different physical and chemical properties following standard procedures [4,5].

Table-1 Map unit description of Santikallur North-5 micro-watershed

SN	Soil Phase	Description	Area in ha.(%)
1	BHLiC2	Belihal series, Deep (100-150cm) having Sandy clay textured soils occurring on Gently sloping (3-5%) with Moderate erosion.	14(4.11)
2	GNTmC3	Guntagola series, moderately shallow (50-75cm) having Clay textured soils occurring on Gently sloping (3-5%) with Severe erosion.	120(36.38)
3	GRJmC2	Gurjapur series, Deep (100-150cm) having Clay textured soils occurring on Gently sloping (3-5%) with Moderate erosion.	38(11.44)
4	KMLmB2	Kalmalli series, Deep (100-150cm) having Clay textured soils occurring on Very Gently sloping (1-3%) with Moderate erosion.	99(29.97)
5	NAGmB2	Naglapur series, moderately deep (75-100cm) having Clay textured soils occurring on Very Gently sloping (1-3%) with Moderate erosion.	60(18.10)
Total			331(100.00)

Note: BHL: Belihal, GNT- Guntagola, GRJ- Gurjapur, KML- Kalmalli, NAG- Naglapur, i- Sandy clay, m-Clay, B-Slope, C- Sloping

Table-2 Physical properties of soils of Santikallur North-5 micro-watershed

SN	Horizon	Depth (cm)	Particle size class and diameter in mm Total (%)		
			Sand (2.0-0.05)	Silt (0.05-0.002)	Clay (<0.002)
1	Belihal	0-11	48.60	8.50	41.20
2		11-26	47.20	7.00	43.50
3		26-53	45.70	6.50	46.40
4		53-77	43.20	9.30	47.40
5		77-89	42.90	8.30	48.70
6		89-121	41.50	10.20	48.90
	SWA		44.26	8.45	44.65
7	Guntagola	0-12	41.60	8.50	47.50
8		12-28	40.50	9.90	48.90
9		28-41	38.20	10.10	49.70
10		41-62	36.80	11.90	50.80
11		62-85	32.90	13.80	52.40
	SWA		37.33	11.28	50.24
12	Gurjapur	0-17	41.40	8.90	44.70
13		17-38	39.70	9.60	47.20
14		38-55	38.50	11.20	48.50
15		55-78	35.80	12.40	50.10
16		78-100	33.40	13.50	51.60
	SWA		37.50	11.25	48.63
17	Kalmalli	0-18	40.30	10.90	47.50
18		18-35	39.20	11.20	48.30
19		35-52	35.70	12.60	49.80
20		52-74	33.10	13.10	53.10
21		74-90	31.80	13.70	54.40
	SWA		35.95	12.31	50.68
22	Naglapur	0-12	41.5	10.30	47.20
23		12-31	39.26	10.60	49.30
24		31-52	36.77	11.30	52.10
25		52-65	32.41	12.90	54.30
26		65-79	29.15	13.80	55.70
	SWA		36.01	11.68	51.68

Statistical Analysis

Karl Pearson's correlation coefficient

Bivariate Pearson's correlation coefficient (r) was performed for X and Y variables of soil parameters.

$$r = \frac{\sum(x - \bar{x})(y - \bar{y})}{\sqrt{\sum(x - \bar{x})^2}\sqrt{(y - \bar{y})^2}}$$

Where, r=Pearson's correlation coefficient

$\bar{x}$ = Mean of x variable

$\bar{y}$ = Mean of y variable

Descriptive statistical analysis and correlation studies were carried out as per the methodology given by Rangaswamy, (2006) [6]. The original data were converted to solum weighted average (SWA) to avoid the outliers from different horizons of each profile. Hence the resultant soil series wise data were used.

*Solum Weighted Average = ∑ [Variable*Horizon Depth(cm)] / [Total Profile Depth (cm)]*

These data have been used to evaluate the land capability classification (Sehgal, 1996) and land suitability. For various field crops (Sorghum, Cotton, Redgram, Bajra and Bengalgram) and horticultural crops (Guava, Custardapple and Amla) based on the soil limitations, climatic regimes and land characteristics the suitable interventions with crop plan were developed. Similar findings were also reported by Leelavathi, *et al*., (2009) [7].

Results and Discussion

Slope

The slope in the Santikallur North-5 Micro-watershed is area varies from very gently sloping (1-3%) to Very strong sloping (41-25%). The slopes have NW-E aspects.

Characterization of soils

Based on slope and its relief structure, the micro-watershed area can be broadly divided into lowland, midland and upland landforms. The detailed soil survey was carried out and identified five soil series with five phases [Fig-3].The soil series Belihal series extended up to a depth of 100-150 cm (deep) with sandy clay soil texture, occurring on gently sloping (3-5%) and moderate erosion with brown (7.5YR 5/3) and medium sub angular blocky structure. Guntagola series extended up to a depth of 50-75cm (moderately shallow) and Gurjapur series extended up to a depth of 100-150cm (deep), both are clay soil texture, occurring on gently sloping (3-5%) and moderate erosion with very dark gray (10YR 3/1) in color. Kalmalli series, deep (100-150cm) having clay textured soils occurring on very gently sloping (1-3%) with moderate erosion. The surface horizon is 0-12 cm thick with very dark brown (10 YR 3/1) in colour. Nagalapur series extended up to a depth of 75-100 cm with clay soil texture, occurring on gently sloping (3-5%) and Moderate erosion. The surface horizon is 0-12 cm thick with very dark brown (10 YR 3/1) in colour. The detailed soil map with phases of soil series is presented and the descriptive legend of soil map is presented in [Table-1].

Physical and chemical properties of soils

In Santikallur North-5 MWS, soil depth varied from moderately shallow to deep. The GNT soil series was moderately shallow (50-75 cm), NAG series were moderately deep (75-100 cm), GRJ, BHL and KML series was deep (100-150 cm). The variability of soil depth may be due to variations in topography and slope gradient [8]. Soils of Santikallur North-5 MWS were having sandy clay loam to clay textural class. The series GNT, GRJ, KML and NAG belongs to clay texture and BHL soil series texture was sandy clay loam. The clay and silt content of soils increased with increasing depth and it was in sand decreased with increase in depth. In this texture class highest SWA in sand texture was recorded in BHL (44.26 %), silt in KML (12.31 %) and clay highest SWA was recorded in Naglapur (51.68 %). The silt and clay had significantly moderate positive association ($p<0.05$). Sand has significantly moderate negative association ($p<0.05$) with clay and it was significantly high negative association ($p<0.01$) with silt. The soil reaction and salinity of soil series were increased with increase in depth. Increase in the content of exchangeable cations in the lower horizons has increased the soil reaction [9] with soil pH 8.62 and EC 0.61 dSm^{-1} of BHL series. The lower value of EC in the surface horizons may be due to free drainage conditions which favoured the removal of released bases by percolating water [10]. It was observed that, the soil OC content decreased with increase in depth. The soil OC content of soil series such as BHL (0.40-0.20 %), GNT (0.45-0.27 %), GRJ (0.55-0.25 %), KML (0.52-0.27 %) and NAG (0.59-0.23 %) were low to medium. The higher soil OC was noticed in surface horizons [Table-2, 3 and 4].

The available nitrogen content decreased with the depth in all the soil series identified. Among BHL (170.00-85.00 kg ha^{-1}), GNT (191.25-106.25 kg ha^{-1}), GRJ (233.75-106.25 kg ha^{-1}), KML (221.00-102.68 kg ha^{-1}) and NAG (250.75-99.65 kg ha^{-1}) soil series, the maximum available nitrogen (SWA) was recorded in NAG (189.65 kg ha^{-1}).

Table-3 Chemical characteristics of soils of Santikallur North-5 micro-watershed

Horizon	Depth	pH	EC	OC	$CaCO_3$	Exchangeable Cations[cmol(p+) kg^{-1}]				CEC[cmol(p+)kg^{-1}]	ESP(%)
	(cm)	(H_2O)	(dSm^{-1})	(%)		Ca	Mg	Na	K		
Belihal	0-11	8.26	0.18	0.40	8.90	28.50	10.00	3.20	0.53	42.85	7.47
	11-26	8.40	0.22	0.39	9.12	28.74	11.25	3.44	0.49	44.54	7.72
	26-53	8.66	0.36	0.33	11.52	29.45	11.49	3.57	0.44	46.15	7.74
	53-77	8.69	0.45	0.27	13.57	31.05	12.06	3.64	0.42	47.97	7.59
	77-89	8.70	0.59	0.21	14.20	31.96	13.54	3.74	0.40	49.70	7.53
	89-121	8.72	1.28	0.20	15.08	32.1	13.66	3.79	0.39	49.94	7.59
	SWA	8.62	0.61	0.28	12.59	30.54	12.22	3.61	0.43	47.37	7.62
Guntagola	0-12	8.39	0.31	0.45	11.80	29.30	10.89	2.65	0.45	44.29	5.98
	12-28	8.43	0.44	0.42	11.32	29.85	11.25	3.02	0.41	45.53	6.63
	28-41	8.55	0.53	0.39	12.17	30.12	11.85	3.32	0.39	46.68	7.11
	41-62	8.65	0.58	0.34	14.32	31.05	12.31	3.55	0.31	48.22	7.36
	62-85	8.72	0.62	0.27	15.20	32.10	12.98	3.74	0.29	50.11	7.46
	SWA	8.57	0.51	0.35	18.11	30.72	12.28	3.47	0.39	51.66	7.02
Gurjapur	0-17	8.34	0.25	0.55	9.85	30.65	10.50	3.31	0.62	45.88	7.21
	17-38	8.52	0.35	0.53	10.52	31.02	11.78	3.50	0.56	47.68	7.34
	38-55	8.54	0.41	0.49	11.47	31.55	13.34	3.61	0.53	49.63	7.27
	55-78	8.61	0.46	0.37	12.08	32.45	12.14	3.79	0.50	49.98	7.58
	78-100	8.64	0.52	0.25	13.80	33.15	13.74	3.88	0.47	51.94	7.47
	SWA	8.53	0.40	0.42	11.64	31.84	12.34	3.63	0.53	49.17	7.38
Kalmalli	0-18	8.02	0.19	0.52	11.34	29.85	10.34	3.18	0.65	45.40	7.00
	18-35	8.14	0.25	0.49	12.84	31.25	11.45	3.24	0.63	47.30	6.89
	35-52	8.27	0.32	0.35	13.67	31.75	12.35	3.45	0.59	49.80	6.92
	52-74	8.44	0.45	0.33	14.50	32.96	13.79	3.51	0.58	52.50	6.68
	74-90	8.59	0.49	0.27	15.27	33.25	13.73	3.67	0.43	54.30	6.75
	SWA	8.29	0.34	0.39	13.53	31.83	12.37	3.41	0.57	49.90	6.84
Naglapur	0-12	8.15	0.20	0.59	12.31	28.01	10.49	3.11	0.55	44.16	7.04
	12-31	8.29	0.25	0.49	14.25	31.54	12.36	3.20	0.51	48.81	6.55
	31-52	8.41	0.26	0.55	14.63	33.15	13.87	3.32	0.49	51.63	6.43
	52-65	8.53	0.29	0.31	15.59	34.52	14.12	3.42	0.47	53.15	6.43
	65-79	8.66	0.30	0.23	16.32	35.02	15.89	3.49	0.45	55.54	6.28
	SWA	8.40	0.26	0.44	14.64	32.53	13.39	3.30	0.49	50.76	6.52

Table-4 Available major and micronutrient status of soils of Santikallur North-5 micro-watershed

Horizon	Depth	Available major nutrients (kg ha^{-1})			Available micronutrients (mg kg^{-1})			
	(cm)	N	P	K	Fe	Mn	Zn	Cu
Belihal	0-11	170.00	39.52	665.20	6.34	5.04	0.45	0.23
	11-26	165.75	37.81	590.10	6.06	4.89	0.31	0.43
	26-53	140.25	29.21	520.90	5.82	4.46	0.13	0.36
	53-77	114.75	27.49	468.20	5.62	4.14	0.09	0.32
	77-89	101.00	24.06	410.20	4.30	4.01	0.04	0.36
	89-121	85.00	20.62	397.10	4.28	3.99	0.03	0.31
	SWA	122.55	28.08	488.42	5.29	4.33	0.139	0.33
Guntagola	0-12	191.25	51.20	551.00	5.92	7.78	0.10	0.21
	12-28	178.50	48.90	510.70	5.43	7.45	0.08	0.25
	28-41	165.75	44.60	457.30	4.91	6.69	0.07	0.38
	41-62	144.50	41.70	443.80	4.50	5.93	0.06	0.42
	62-85	106.25	37.80	416.50	3.99	4.55	0.04	0.31
	SWA	150.40	43.78	466.20	3.89	6.22	0.06	0.32
Gurjapur	0-17	233.75	47.60	551.00	6.59	8.89	0.13	0.38
	17-38	225.25	44.50	510.70	6.04	7.65	0.11	0.22
	38-55	208.25	41.40	457.00	5.88	6.99	0.09	0.21
	55-78	157.25	40.20	443.50	5.49	6.05	0.08	0.25
	78-100	106.25	35.30	416.60	5.03	5.68	0.06	0.24
	SWA	181.98	41.48	472.26	5.75	6.94	0.09	0.25
Kalmalli	0-18	221.00	52.60	695.50	6.78	16.18	0.12	0.22
	18-35	208.25	48.50	712.20	6.12	14.11	0.15	0.29
	35-52	148.75	45.20	670.20	5.94	12.66	0.06	0.34
	52-74	140.25	41.80	622.30	5.26	4.58	0.04	0.45
	74-90	102.68	39.10	604.90	4.28	6.9	0.03	0.26
	SWA	164.17	45.38	659.87	5.68	10.63	0.07	0.31
Naglapur	0-12	250.75	53.80	578.20	6.82	7.64	0.15	0.37
	12-31	208.25	48.90	544.50	6.64	6.07	0.12	0.26
	31-52	233.75	45.20	502.90	6.34	5.05	0.03	0.32
	52-65	131.75	43.70	497.20	6.10	5.43	0.03	0.25
	65-79	99.65	38.50	470.50	5.44	6.23	0.01	0.20
	SWA	189.65	45.96	517.66	6.28	6.27	0.06	0.28

Table-5 Soil suitability for major crops in Santikallur North-5 micro-watershed

Soil phase	Sorghum	Cotton	Redgram	Bajra	Bengalgram	Guava	Custardapple	Amla
BHLiC2	S2l	S2l	S2l	S2l	S2t	S2tl	S2l	S2l
GNTmC3	S2rl	S3rl	S2rtl	S3rtl	S2l	S3rtl	S2rl	S2rl
GRJmC2	S1	S3l	S2tl	S3tl	S1	S3tl	S2l	S2l
KMLmB2	S1	S1	S2t	S3t	S1	S3t	S1	S1
NAGmB2	S1	S3r	S2t	S3t	S1	S3rt	S1	S1

Table-6 Association between physical and chemical properties of soil profile samples (SWA) of Santikallur North-5 MWS

Parameter	Sand	Silt	Clay	pH	EC	OC	$CaCO_3$	Ca	Mg	Na	K	CEC	ESP	N	P	K_2O	Fe	Mn	Zn
sand	1																		
silt	-0.989**	1																	
clay	-0.907*	0.879*	1																
pH	0.717	-0.777	-0.729	1															
EC	0.845	-0.825	-0.827	0.827	1														
OC	-0.867	0.823	0.743	-0.624	-0.934*	1													
$CaCO_3$	-0.313	0.268	0.503	0.068	0.060	-0.064	1												
Ca	-0.722	0.692	0.680	-0.735	-0.971**	0.929*	-0.256	1											
Mg	-0.450	0.360	0.661	-0.431	-0.746	0.649	0.100	0.767	1										
Na	0.649	-0.621	-0.902*	0.703	0.719	-0.515	-0.478	-0.590	-0.773	1									
K	-0.480	0.553	0.278	-0.776	-0.680	0.607	-0.623	0.716	0.160	-0.154	1								
CEC	-0.806	0.756	0.859	-0.340	-0.490	0.530	0.803	0.308	0.380	-0.672	-0.123	1							
ESP	0.812	-0.780	-0.976**	0.749	0.832	-0.691	-0.450	-0.703	-0.766	0.969**	-0.266	-0.765	1						
N	-0.834	0.781	0.709	-0.568	-.915*	.997**	-0.084	0.924*	0.664	-0.482	0.576	0.506	-0.659	1					
P	-0.995**	0.978**	0.934*	-0.693	-0.821	0.835	0.401	0.683	0.468	-0.692	0.401	0.857	-0.842	0.801	1				
K_2O	-0.379	0.494	0.397	-0.880*	-0.467	0.203	-0.164	0.371	0.051	-0.453	0.709	0.035	-0.433	0.135	0.353	1			
Fe	-0.172	0.170	0.161	-0.528	-0.653	0.547	-0.712	0.792	0.597	-0.248	0.733	-0.320	-0.270	0.556	0.111	0.363	1		
Mn	-0.689	0.789	0.539	-0.864	-0.584	0.474	-0.061	0.463	-0.040	-0.366	0.773	0.312	-0.467	0.407	0.651	0.862	0.217	1	
Zn	0.945*	-0.913*	-0.949*	0.582	0.715	-0.726	-0.599	-0.551	-0.471	0.739	-0.185	-0.951*	0.861	-0.695	-0.973**	-0.247	0.060	-0.527	1
Cu	0.488	-0.432	-0.226	0.183	0.605	-0.811	0.432	-0.718	-0.370	-0.047	-0.532	-0.106	0.154	-0.843	-0.426	0.173	-0.558	-0.142	0.278

Table-7 Proposed Crop Plan for Santikallur North-5 Micro-watershed

Proposed Land Use Class	Soil Map Units	Survey Number	Field Crops	Horticulture Crops	Suitable Interventions
LMU-1	GNTmC3	Hunkunti : 40,41,39,38,50,51,35, 36,37,32,130,33,131/1, 30	Sole crop: Sorghum, Bajra, Navni, Red gram, Green gram, Cotton, Maize, Sun flower, black gram, bengal gram, ground nut, maize.	Fruit crops: Sapota, Jamun, Guava, Tamarind, Lime, Musambhi, Custard apple, Jackfruit, Amla, pomegranate. Vegetables: Clusterbean, bhendi, Phundi, Brinjal, Onion, Chilli, tomato, Green leaf, Cury leaf. Flowers: Gaillardia, Spider lilly, Mari gold.	Deep and wider size pit, Drip irrigation with suitable soil and water conservation measures Cultivation on raised beds with mulches and drip. Graded bunds and strengthening of field bunds
LMU-2	NAGmB2	Hunkunti: 31,29,131/2	Sole crop: Sorghum, Bajra, Navni, Red gram, Green gram, Cotton, Maize, Sun flower, black gram, bengal gram, maize, ground nut.	Fruit crops: Sapota, Jamun, Guava, Tamarind, Lime, Musambhi, Custard apple, Jackfruit, Amla, pomegranate, Mango. Vegetables: Clusterbean, bhendi, Phundi, Brinjal, Onion, Chilli, Green leaf, Cury leaf. Flowers: Gaillardia, Spider lilly, Mari gold.	Cultivation on raised beds with mulches and drip irrigation system. Drip irrigation with suitable soil and water conservation measures. Graded bunds and strengthening of field bunds
LMU-3	BHLiC2	....	Sole crop: Sorghum, Bajra, Navni, Red gram, Green gram, Cotton, Maize, Sun flower, black gram, bengal gram, maize, ground nut.	Fruit crops: Sapota, Jamun, Guava, Tamarind, Lime, Musambhi, Custard apple, Jackfruit, Amla, pomegranate, Mango. Vegetables: Clusterbean, bhendi, Phundi, Brinjal, Onion, Chilli, Green leaf, Cury leaf. Flowers: Gaillardia, Spider lilly, Mari gold.	Cultivation on raised beds with mulches and drip irrigation system. Drip irrigation with suitable soil and water conservation measures. Graded bunds and strengthening of field bunds
LMU-4	GRJmC2	....	Sole crop: Sorghum, Bajra, Navni, Red gram, Green gram, Cotton, Maize, Sun flower, black gram, bengal gram, maize, ground nut.	Fruit crops: Sapota, Jamun, Guava, Tamarind, Lime, Musambhi, Custard apple, Jackfruit, Amla, pomegranate, Mango. Vegetables: Clusterbean, bhendi, Phundi, Brinjal, Onion, Chilli, Green leaf, Cury leaf. Flowers: Gaillardia, Spider lilly, Mari gold.	Cultivation on raised beds with mulches and drip irrigation system. Drip irrigation with suitable soil and water conservation measures. Graded bunds and strengthening of field bunds
LMU-5	KMLB2	Hunkunti: 26,26,28,77,76/1,81,80, 76/2, 52,82,49,45,44, 42,43 Motur: 86,87,88,97,98/1,99/1,99/2, 107	Sole crop: Sorghum, Bajra, Navni, Red gram, Green gram, Cotton, Maize, Sun flower, black gram, bengal gram, maize, ground nut.	Fruit crops: Sapota, Jamun, Guava, Tamarind, Lime, Musambhi, Custard apple, Jackfruit, Amla, pomegranate, Mango. Vegetables: Clusterbean, bhendi, Phundi, Brinjal, Onion, Chilli, Green leaf, Cury leaf. Flowers:Gaillardia, Spider lilly, Mari gold.	Cultivation on raised beds with mulches and drip irrigation system. Drip irrigation with suitable soil and water conservation measures. Graded bunds and strengthening of field bunds

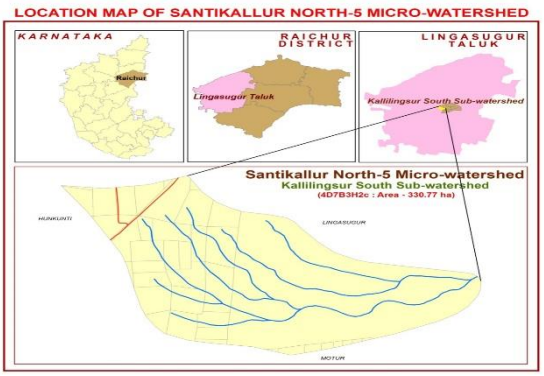

Fig-1 Location map of Santikallur North-5 Micro-watershed, LingsugurTaluk, Raichur District

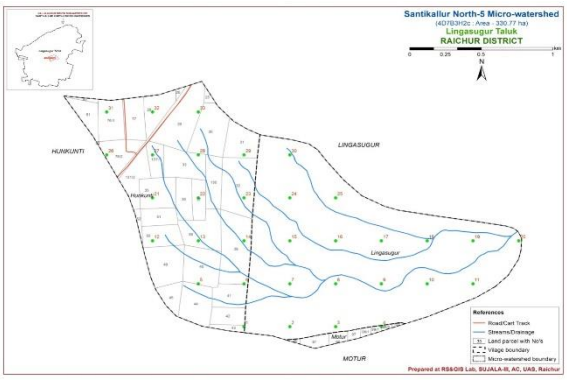

Fig-2 Cadastral map of Santikallur North-5 Micro-watershed

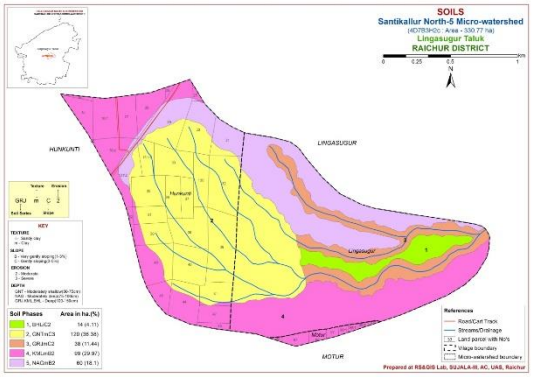

Fig-3 Soil map of Santikallur North-5 Micro-watershed

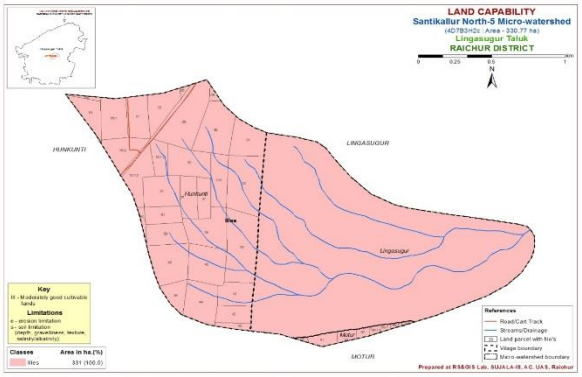

Fig-4 Land capability classes in Santikallur North-5 Micro-watershed

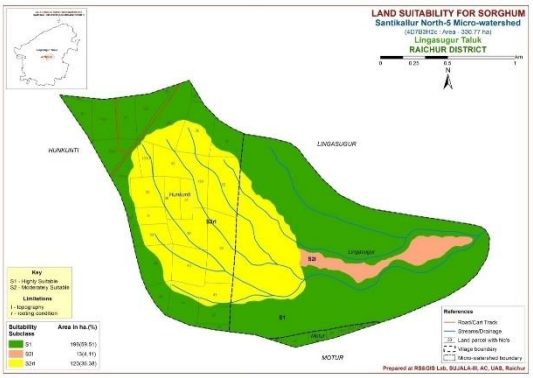

Fig-5 Land suitability map for Sorghum in Santikallur North-5 Micro-watershed

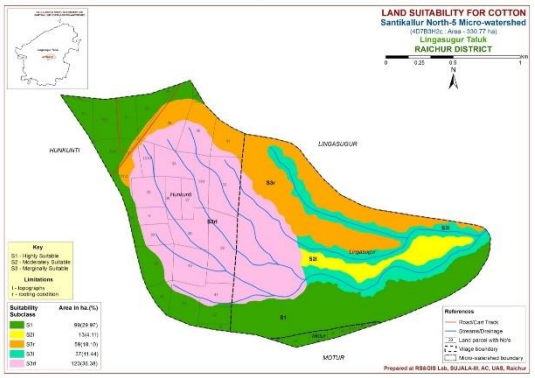

Fig-6 Land suitability map for Cotton in Santikallur North-5 Micro-watershed

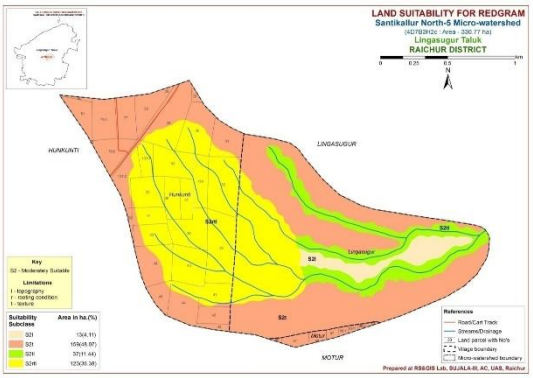

Fig-7 Land suitability map for Redgram in Santikallur North-5 Micro-watershed

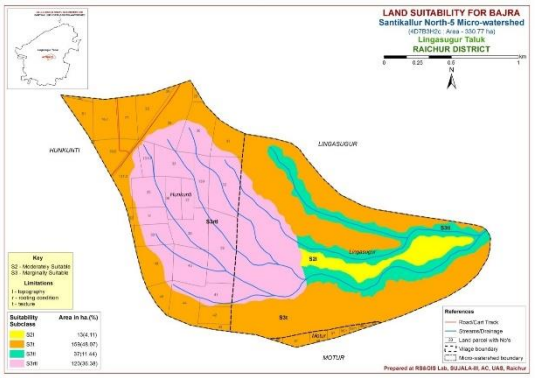

Fig-8 Land suitability map for Bajra in Santikallur North-5 Micro-watershed

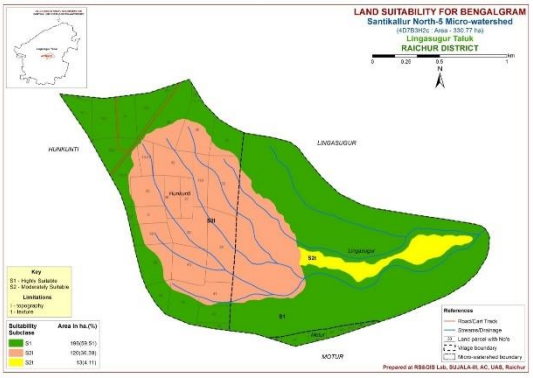

Fig-9 Land suitability map for Bengal gram in Santikallur North-5 Micro-watershed

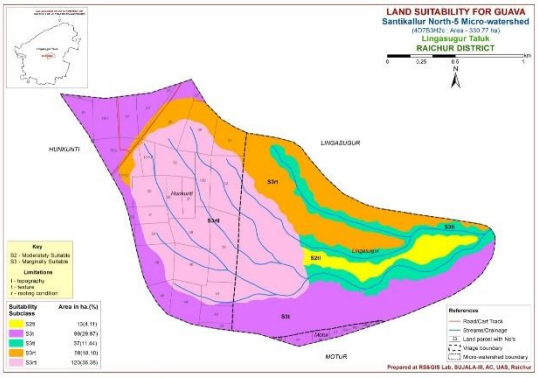

Fig-10 Land suitability map for Guava in Santikallur North-5 Micro-watershed

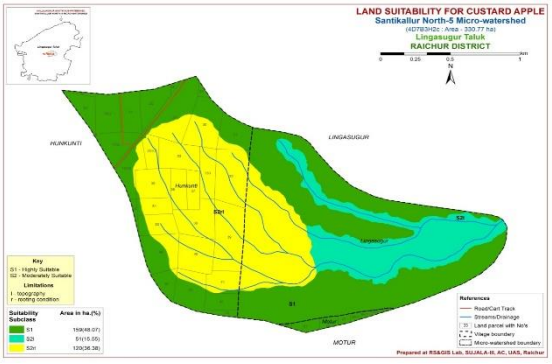

Fig-11 Land suitability map for Custard Apple in Santikallur North-5 Micro-watershed

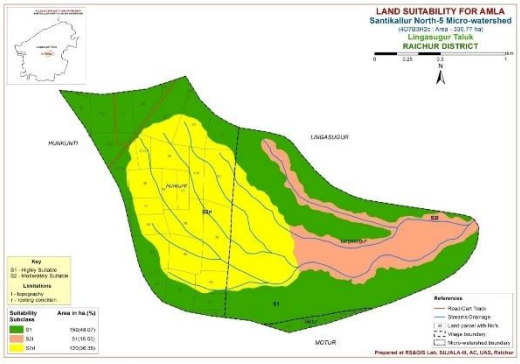

Fig-12 Land suitability map for Amla in Santikallur North-5 Micro-watershed

The soil OC and nitrogen were significantly highly positively associated ($p<0.01$). This could be attributed to low soil OC coupled with low nitrogen fertilization application leading to nitrogen deficiency. Low organic matter content in these areas due to low rainfall and low vegetation cover facilitate faster degradation and removal of organic matter leading to nitrogen deficiency [11].

The available phosphorous content in soil series such as BHL (39.52-20.62 kg ha^{-1}), GNT (51.20-37.80 kg ha^{-1}), GRJ (47.60 –35.3 kg ha^{-1}), KML (52.60-39.10 kg ha^{-1}) and NAG (53.80-38.50 kg ha^{-1}) were medium to high, among which NAG (45.96 kg ha^{-1}) has recorded highest. Available phosphorous content decreased with the soil depth in all the pedons studied, this could be attributed to higher removal than replenishment in the sub soil and high phosphorous fixation capacity as well as less mobility of P and significantly high negative association with Zn ($p<0.01$), Similar result were quoted by Mathews *et al*., (2009) [22]. The higher content of K_2O in series KML (659.87 kg ha^{-1}) might be due to the predominance of potash rich micaceous and feldspar minerals in parent rocks [12]. High content of available potassium found in surface horizon than the sub-surface horizons, may be due to more intense weathering, release of labile potassium from organic residues and application of low K fertilizers[13]. The higher content of SWA value of exchangeable calcium and magnesium of soil series NAG (32.53 and 13.39 cmol (p+) kg^{-1}) recorded respectively.

The calcium and Magnesium were increased with increase in soil depth. Comparing these ions (Mg^{2+}, Na+ and Ca^{2+}) it was clear that Mg2+ was present in low amount than Ca^{2+}, because of its higher mobility. These results are in conformity with findings of [14]. The Calcium was significantly moderate positive association ($p<0.05$).

The available iron in BHL soil series ranged from (6.34 to 4.28 mg kg^{-1}), GNT (5.92 to 3.99 mg kg^{-1}), GRJ (6.59 to 5.03 mg kg^{-1}), KML (6.78 to 4.28 mg kg^{-1}) and NAG (6.82 to 5.44 mg kg^{-1}) were sufficient, among which NAG (6.28 mg kg^{-1}) has recorded highest. The available Fe content decreased significantly with the increase in the depth. Low Fe content at lower depths may be due to precipitation of Fe by $CaCO_3$ and decreased its availability [15]. Iron is negatively correlated with $CaCO_3$. The available manganese and copper showed highest SWA in KML series (10.64 mg kg^{-1} and 0.33 mg kg^{-1}) respectively. The available manganese and copper content was decreased with the depth. The sufficient manganese and copper content in the study area might be due to the parent material [16].The available zinc highest SWA recorded in BHL (0.139 mg kg^{-1}) series. The available zinc content decreased with the soil depth. The larger extent of zinc deficiency was due to calcareousness, high pH and low organic matter, which might have resulted in the formation of insoluble compounds of zinc. This might have reduced the availability of zinc. Similar findings were observed by [17].

Land capability classification

Land capability classification is an interpretive grouping of soils mainly based on the inherent soil characteristics, external land features and environmental factors that limits the use of the land [18]. Morphological features of soil units [Table-1] are matched with the criteria for land capability classification [19]. The land capability classification of mapping units and their extent in watershed is presented in [Fig-4]. Based on soil properties, the soils of Santikallur North-5 micro-watershed of Lingasugur taluk have been classified as IIIes area under 331 ha with limitations of texture, drainage, fertility and topography. Among all the five series, Belihal series, Guntagola series, Gurjapur series, Kalmalli series sand Naglapur series were classified under capability class III and most of the crops like green gram, sorghum, pearl millet and guava are moderately suitable [Fig-3]. Similar findings were also reported by [20].

Suitability of soils for crops

Soil site suitability of all the mapping units was assessed for major crops grown in the area. The optimum requirements of a crop are always region specific. Climate and soil-site characteristics play significant role to maximize the crop yields. The soil morphological characteristics from the study area [Table-5] and climatic regimes were matched with land suitability criteria for different crops [21].

The land suitability assessment for field crops in Santikallur North-5 MWS showed that [Table-6] an area of 17 ha (2.72%) was highly suitable for crops like Amla, Custardapple 159ha (48.07%), Bengalgram 196.84 ha (59.51%), Cotton, 99 ha (6.44%) area. For moderately suitable crops like Bajra, Guava, Cotton, Mango, 13.60 ha (4.11%), Redgram 330.78ha (100.00%), Sorghum 133.94 ha (40.49%) area and marginally suitable crops like Bajra, Guava 317.18 ha (95.89%), Cotton 218.06 ha (65.92%) area with limitation to rooting condition, gravel slope and texture.

Conclusion

The soils of Santikallur North-5 micro-watershed identified five soil series further divided into five soil-phases with sandy clay to clay textured soils slope varies from very gently to gently sloping. Soil available nitrogen (85 to 250.75 kg ha^{-1}) was low and it has significantly strong positive correlation with SOC ($p<0.01$). The available phosphorus was low to medium in range (20.62 to 53.80 kg ha^{-1}) and because of low mobility of available P, it was negatively correlated with Zn ($p<0.01$). ESP has significantly strong positive association with Na ($p<0.01$), and it was significantly strong negative association with clay ($p<0.01$). Land capability sub classes in the study area were IIIes with limitations of soil erosion, texture, soil drainage, soil fertility and topography. The land was highly suitable (S1) for sorghum, Bengal gram, Custard apple and Amla and moderately suitable (S2) for Cotton, Red gram, Bajra and guava with limitations of rooting and topography. The crop planning showed that mapping units restricted for different crops can be managed by adapting the suitable soil and water conservation practices such as contour farming, crop rotation, mulching and conservation tillage etc. Hence, it can be concluded by detailed LRI crop suitability and land capability classification assessment at micro watershed level will help in development of sustainable agricultural land use plans using geospatial techniques at parcel level.

Application of research: Detailed land resource inventory for agricultural and hydrological resource action plan at micro-watershed level.

Research Category: Detailed land resource inventory, Watershed development

Abbreviations: LRI-Land Resources Inventory

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****Principal Investigator or Chairperson of research: Dr Rajesh N L**
University: University of Agricultural Sciences, Raichur, 584104, Karnataka, India
Research project name or number: "Support for improved program integration in rainfed areas"

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Lingasugur taluk of Raichur district, Karnataka

Cultivar / Variety / Breed name: Sorghum, Bengalgram, Custard apple, Amla

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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