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Research Article

LAND EVALUATION FOR SUITABILITY ANALYSIS OF SITE SPECIFIC PIGEON PEA (*Cajanus cajan*) - SORGHUM (*Sorghum bicolor*) - A CASE STUDY OF MATKI-3 MICROWATERSHED, GULBARGA DISTRICT, KARNATAKA, INDIA

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Abstract: The present study was carried out to examine the land suitability evaluation of Matki-3 microwatershed (686 ha) of Aland Taluk, Kalaburgi District, Karnataka, India for selected land utilization types pigeon pea (*Cajanus cajan*) and Sorghum (*Sorghum bicolor*). The land mapping units of the study area, prepared from land resource information obtained from detailed soil survey at 1:10000 scale using IRS-P6-LISS- IV merged with Cartosat-1 and GIS technique, were used for the purposes of land evaluation. The methodology used for land suitability evaluation was GIS-based multi-criteria evaluation following FAO (1976) guidelines involving matching diagnostic land qualities against crop requirements and assigning suitability rates for each land qualities. Seven Soil series were identified and derived twenty four mapping units as phases of soil series. The land suitability analysis results revealed that 393 ha (58%) of total area is suitable for Pigeon pea and sorghum as against the current land use of 645 ha with limitations of soil depth, sloping lands and gravelliness. In addition to land evaluation, suitable crop interventions suggested for enhancing productivity of these crops under drought prone areas of Karnataka.

Keywords: GIS, Land evaluation, Soil mapping units, soil suitability

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Introduction

Land suitability potential evaluation is an important step to detect the environmental limit in sustainable land use planning. It deals with the assessment of land performances for the specific use that is crop production. Land evaluation constitutes a valuable resource inventory that is linked with the survival of life on the earth and involves the process of evaluation of a particular tract of land for specific purposes involving the execution and interpretation of data of natural resources and other related aspects of land in order to identify and make a comparison of promising kinds of land uses. Hence, depending on the suitability of the mapped land units for a set of crops, optimum cropping patterns could be suggested by taking into consideration the present cropping system and the socio-economic conditions of the farming community [1]. In India, the land resources available for agriculture are shrinking. The occurrence of drought in three to five years interval due to shortfall in seasonal rainfall in cropping season or insufficient soil-moisture availability throughout prolonged dry spells between successive rainfall events [2]. Appraisal of land is essential for its optimal use for agricultural development on sustainable basis. Accordingly, Soil survey and land evaluation helps better land use planning and management with realization of inherent potentials and constraints of biophysical factors in the region [3]. The soil and land resource inventories made so far in Karnataka had limited utility because the surveys were of different types, scales and intensities on various land resources for all the villages/ watersheds in a time bound manner that would help to protect the valuable soil and land resources and also to stabilize the farm production. Therefore, the land resource inventory required for farm level planning is the one which investigates all the parameters which are critical for productivity *viz*., soils, site characteristics like slope, erosion, gravelliness and stoniness, climate, water, topography, geology, hydrology, vegetation, crops, land use pattern, animal population, socio-economic conditions, infrastructure, marketing facilities and various schemes and developmental works of the government etc and can be utilized for land use planning and development [4]. In the ordinal century, to steer the agricultural achievements towards the path of Association in 'evergreen revolution' there is a need to combine the standard information with frontier technologies. Information and communication technology; remote sensing technology; geographical information systems (GIS) area unit the tools of such frontier technologies which would facilitate in creating agricultural management systems; designing for sustainable agriculture; and establish new areas (through development of wastelands) into productive agriculture. The role of remote sensing and GIS in agricultural applications is broadly categorized into a pair of groups-inventorying/mapping and management. The sustainable agricultural land use achievable using remote sensing and GIS information supporting integration of land capability, land productivity; soil suitability; terrain characteristics and socio- economic *etc*. [5]. In the dry ecosystem, climatic variability in terms of mean annual rainfall (MAR) and mean annual temperature (MAT) results in affect crop performance and often leads to low crop yield [6]. The large scale mapping using IRS-P6-LISS-IV merged with cartosat were used in generation of land resource data at village level [7-10]. The watershed management programs are aimed at designing suitable soil and water conservation measures, productivity enhancement of existing crops, crop diversification with horticultural species, greening the wastelands with forestry species of multiple uses and improving the livelihood opportunities for landless people. The objectives can be met to a great extent when an appropriate Natural Resources Management (NRM) plan is prepared and implemented.

It is essential to have site specific Land Resources Inventory (LRI) indicating the potentials and constraints for developing such a site specific plan [11]. The district economy is mainly dry land agriculture with an irrigated area of 18.8% of the net area sown (below the state average of 25 per cent). The district is a drought prone with an occurrence of drought once in three years [12]. The agricultural landscapes in rural sectors of drought prone Gulberga district and provide an opportunity to look into the reflective realties of drought and difficulties faced by farmers to enhance farm productivity with rudimentary farming systems. In the present study, a land suitability evaluation in a watershed has been carried out through close examination of the indicators of land suitability. Satellite images of the study area have been classified for land use/land cover map preparation, while toposheet and ancillary data have been used for slope maps and soil properties determination. An integrated land suitability potential (LSP) index was computed considering the contribution of various parameters of land suitability. The watershed was categorized as good, fair, moderate, average, poor and not suitable by adopting the logical criteria. These categories were arrived at by integrating the various layers with corresponding weights in a geographical information system (GIS). For this purpose, in this study, the land use suitability classification was performed for by integrating the actual soil-land information with land evaluation for crop planning at landscape level within the watershed. The objectives of present study are: (i) to characterize and classify soils and then mapping for land evaluation and (ii) to integrate soil-land information in GIS environment for assessing their suitability to locally adopted crops for crop development in the watershed level. The study put emphasis on that based on the soil properties, terrain characteristics with analyzing present landuse the spatially distributed agriculture potential zones can be categorized in watershed.

Materials and Methods

Description of the study area

Matki-3 microwatershed in Aland taluk (170 36'-170 38' N and 770 28'-770 31' E) covers 686 hectare [Fig-1]. This area comes under the agroclimatic zone of north eastern transition zone with mean annual rainfall of 740 mm with 46 rainy days and also comes under Semi arid Deccan Plateau, hot arid ecosubregion [13]. Of the total rainfall, seventy three per cent of rainfall (540 mm) is received during the southwest monsoon (June to September), seventeen per cent during the north-east monsoon (October to early December) and the remaining ten per cent (74 mm) during the remaining period. December is the coldest with mean daily minimum temperature of 10ºC but in summer (May) the temperature rises to 45 ºC with a relative humidity of 26%. The soil water balance diagram [14] shows that this area has average potential evapo-transpiration (PET) of 159 mm with a variation of 115 mm in December to 232 mm in May exceeding precipitation in all the months except August and September [Fig-2]. The length of crop growing period (LGP) is 120-150 days and starts from 3rd week of May to first week of October. The agroclimate is characterized as ustic soil moisture regime and soil temperature regime [15] at an elevation of 300-450 m above mean sea level. The cropping pattern is dominated by food crops, which accounts for 94% of the net area sown. Sorghum, Pigeon pea and sunflower are the major crops, occupying 76 per cent and 66 per cent of the net area sown. The district is called 'Tur' bowl of the state as the area under Pigeon pea occupies 65.7 per cent. The system of farming and the cropping pattern reveals low levels of living of the people in rural areas. This crop assumes a great importance in Karnataka agricultural economy, which ranks second in area (0.51 mha) and fifth in terms of production (0.25 mt) in the country. But ironically the yield of this crop is below all India average. It is grown both as a sole crop and intercrop with pearl millet, groundnut, chickpea, green gram and cowpea. It is largely grown in the northern parts of the state especially in Gulbarga, Raichur, Bidar and Bellary districts of Karnataka predominantly under rainfed cropping system [16]. The productivity of pigeon pea in Karnataka is 581 kg ha^{-1}, which is much below the national average of 671 kg ha^{-1} (Govt of India 2010).

Field survey

Land resource inventory on 1:10000 scale using false colour composites of Cartosat-1 and LISS-IV merged satellite data was carriedout with the preparation of landform form map as prerequisite for field survey as per standard guidelines given in Soil Survey Manual [17, 18].

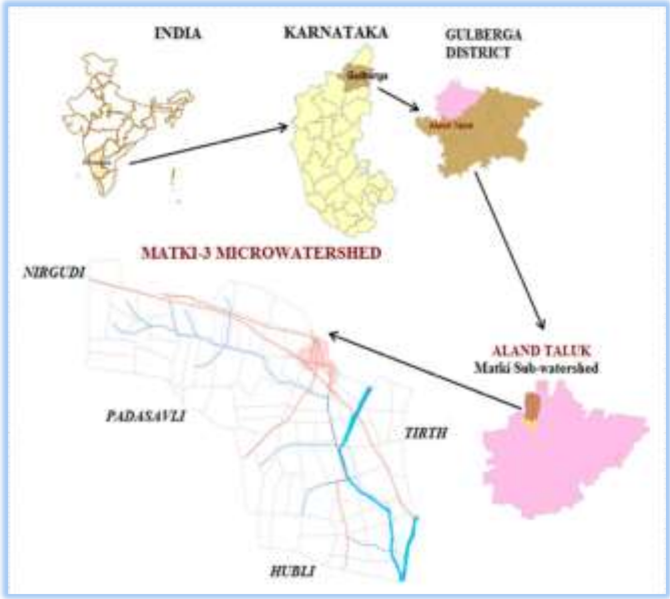

Fig-1 Location map of Matki-3 Microwatershed

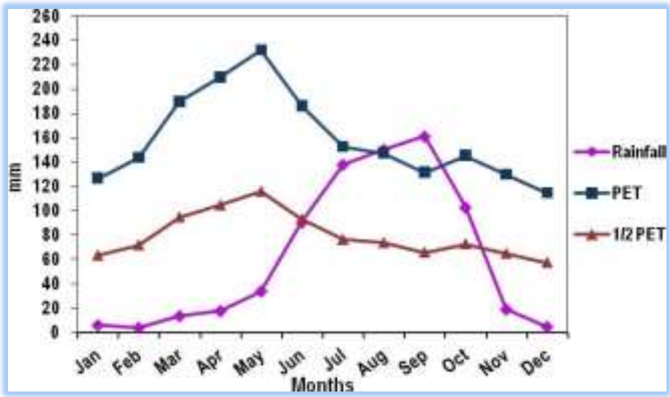

Fig-2 Rainfall distribution in Aland Taluk, Gulbarga District

The intensive field traverse was made to check field boundaries and to acquaint with landscape patterns. The soil transects were selected at respective landscape elements and dug out 16 soil profiles and recorded latitude/longitude and elevation of each site with the help of Global Positioning System (GPS). Morphological descriptions of each pedon were recorded [19] and classified upto family level as per [20]. The soil map was generated with six soil series identified and derived 15 soil mapping units defined as phases of series in GIS environment with ArcGIS ver.10.2.

Laboratory analysis

Horizon wise soil samples were collected and sieved air dry samples through 2 mm sieve for fine earth fraction. The routine and standard procedures were used for bulk density by clod method, pH, Electrical conductivity (1:2.5 soil water ratio) by [21] in the supernatant suspension of 1:2.5 (soil: water ratio). The method described by [22] was used for cation exchange capacity (CEC) estimation. Soil organic carbon (OC) was estimated using the method [23] and expressed in percentage. 1N ammonium acetate (NH_4OAc) solution at pH extractable potassium (K^+) was determined by Flame Photometer [21]. According to the method of [24] DTPA-extractable micronutrients Fe, Mn, Zn and Cu were extracted by 0.005 M DTPA at pH 7.3 and the concentration of the micronutrients were estimated using atomic absorption spectrophotometer (Agilent Technologies, 200 series AA model). Available phosphorus determined by Olsen method [25] and available S by $CaCl_2$ extraction method [26]. The available Boron estimated by the Azomethine-H method by using LabIndia (analytical) UV/VIS spectrophotometer [27].

Fertility status of N, P, K and S were interpreted as low, medium and high and that of DTPA extractable zinc, iron, copper and manganese interpreted as deficient, sufficient and excess by following the criteria [28].

Land evaluation for crops

Land evaluation classification was undertaken according to the FAO [4, 29-31] system to assess the suitability of the studied area soils for agriculture and development. The FAO-SYS system had divisions of suitability classes that indicate degree of suitability. In FAO land suitability classification, two orders are recognized. The order S- Suitable and order N-Not suitable. The orders have classes, subclasses and units. Order-S has three classes, Class S1- Highly suitable, Class S2-Moderately suitable and Class S3- Marginally suitable. Order N has two classes, N1- Currently not suitable and N2- Permanently not suitable. The steps followed in land evaluation for crops and in deriving thematic map of suitability zones were as follows [Fig-3]:

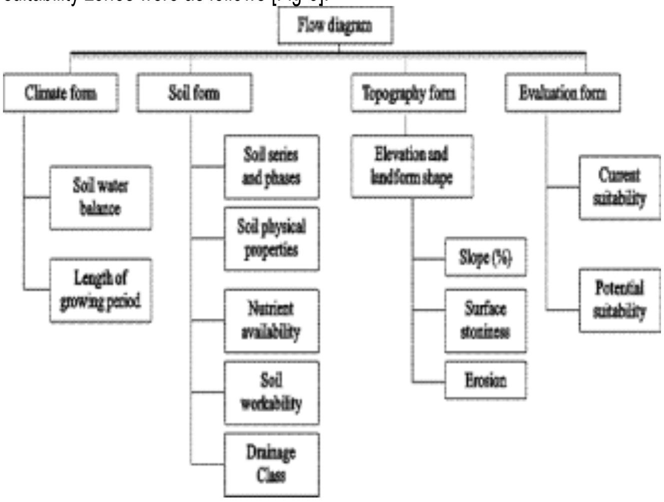

Fig-3 Flow diagram of site specific land evaluation for crop management of Matki-3 Microwatershed

Step 1. Soil map with limiting biophysical parameters was used to define limitations of each series.

Step 2. Development of land capability of soil units as per the guidelines of IARI manual [17].

Step 3. Suitability for crops as per the frame work of FAO [4] and [32].

Step 4. Development land management units considering biophysical and homogeneity of soil units in terms of properties and land use for making decisions on crop plans for defined priority areas suitable for crops under GIS environment.

Results and discussions

Brief description of basaltic soil resources occurring in the microwatershed is given below in [Table-1]. The seven soil series identified and classified upto family in the subgroups level as (i) Margutti: clayey, mixed, isohyperthermic family of Typic Ustorthents; (ii) Novinihala: loamy, mixed, isohyperthermic family of Paralithic Haplustepts; (iii) Bhimanahalli: clayey, mixed, isohyperthermic family of Paralithic Haplustepts (iv) Kalamundargi; Clayey, skeletal, mixed, isohyperthermic family of Paralithic Haplustepts (v) Gutti: Fine, Montmorilloxitic, isohyperthermic family of Typic Haplusterts; (vi) Kamalapur: Fine, montmorillonitic, isohyperthermic family of Typic Haplusterts; (vii) Rajanala: Very fine, montmorillonitic, isohyperthermic, Typic Haplusterts [20]. The Gulberga district lies in the northern plains of Karnataka and falls under semiarid tract of the state and is categorized as drought prone with average annual rainfall of 785 mm. The climate is characterized as ustic soil moisture regime and isohyperthermic soil temperature regime [33].

Soil map

In the present study, fifteen mapping units defined as phases of soil series was used to derive soil map of Matki-3 microwatershed [Fig-4]. The map shows that Margutti (MGT) series with twelve phases identified with variations in gravelliness, slope and severity of erosion. This series covers 265.47 ha (39% of total area). The mapping unit (MGTiC3g3, MGTiD3g3 and MGTmC3g3 as in soil map) covers 7.18 per cent with severe limitation of gravelliness and very low available water holding capacity. These land units are concentrated in the middle and foot slopes of microwatershed indicating high degree of sheet erosion. Bhimanahalli soil series covering 157.28 ha (22.91%) has three phases *viz*., (i) BHImB1 having 16.30 ha (2.37%) area very shallow (25-50 cm) clayey soils on 1-3% slopes with slight erosion, (ii) BHImB1g1 covering 130.34 ha (18.99% of total area) has clayey texture, occurring on 1-3% slopes, slightly eroded and gravelly (15 to 35%) and (iii) BHImB1g2 having an area of 10.64 ha (1.55%) has clayey soils on 1-3% slopes with slight eroded and very gravelly (35-60%). These land units are mostly concentrated in central, southern with horizontal bend towards north western fringes of microwatershed [Fig-4]. Kalamundargi soil series (KGI) covering an area of about 23 ha (3.38%) with only one soil phase KGImB2g2 are shallow (25-52 cm) clayey soils on 1-3% slopes with moderate eroded with very gravelly (35-60%). The Novinihala soils series (NHA, 36.75 ha, 5.36% of total area) are shallow with two phases *viz*., (i) NHAmB1g1 covering 33.20 ha *i.e*., 4.84% of the watershed, but (ii) NHAmB2g1 has 3.55 ha with limitations of gravelly and slight to moderate erosion. This unit is mostly located in central parts of the watershed. The Gutti soil series (GTT) are moderately shallow with three phases (i) GTTmB 146.25 ha (6.74%), (ii) GTTmB1g 19.48 ha (1.38%) and GTTmB 26.27 ha (0.91%) (Eastern zone) identified with limitations of slight to moderate erosion and gravelliness. The consociations of Kamalapur (KMP) and Rajanala (RNL) soils are clayey and moderately to very deep with KMPmB 19.46 ha (1.38%), KMPmB1g1 16.23 ha (2.36%) and RNLmB1 89.18 ha (12.99%) with 1-3 per cent slopes and slightly eroded. These land units are concentrated in the central and northwestern zones of microwatershed.

Climate analysis

Karnataka is located on the western coast of peninsular India, enclosed between 11.500 N to 18.500 N and 740 E to 78.50 E. The study area Gulbarga belongs to semiarid climatic conditions. The southwestern monsoon rainfall occurs mainly in June to September and constitutes over 75% of the total rainfall. Normal rainfall of the Gulbarga district is 777 mm actual rainfall is 881.10 mm. December is the coldest month but in summer, maximum temperature goes upto 45 ºC. Relative humidity varies from 26% in summer and 62% in winter. Of the total rainfall, maximum

Table-1 Description of soil series under basaltic soil resources in Matki-3 Microwatershed

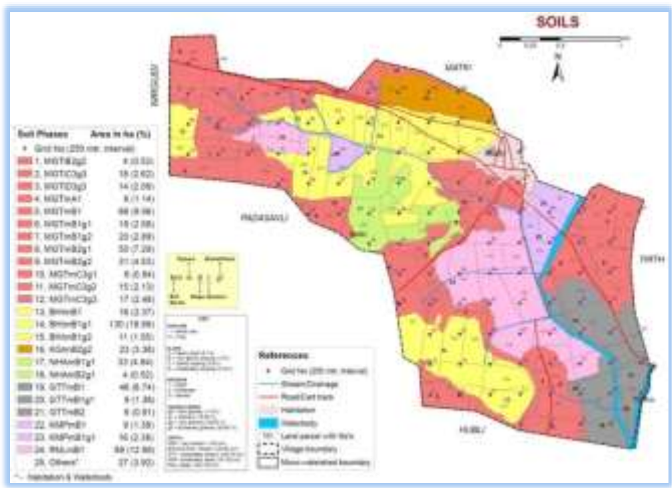

Fig-4 Soil phase units map of the study area Matki-3 Microwatershed

of 595 mm is received during the south–west monsoon period from June to September, the north-east monsoon from October to early December contributes about 116 mm, and the remaining 75 mm during the rest of the year. December is the coldest month with mean daily maximum and minimum temperatures being 29.5 0C and 150 to 10 0C respectively. During peak summer, temperature shoots up to 45 0C. Relative humidity varies from 26 per cent in summer to 62 per cent in winter. Rainfall distribution is shown in [Fig-2]. The average potential evapotranspiration (PET) is 150 mm and varies from a low of 115 mm in Land

Table-1 Description of soil series under basaltic soil resources in Matki-3 Microwatershed

	Margutti (MGT) Series: Marguti soils are very shallow (<25 cm), well drained, have very dark grayish brown to dark brown clay soils. They have developed from basalt and occur on very gently sloping to moderately sloping uplands. The thickness of A horizon ranges from 7 to18 cm. Its colour is in 10YR and 7.5 YR hue with value 3 to 4 and chroma 2 to 3. The thickness of B horizon ranges from 18 to 24 cm. Its colour is in 10 YR hue with value 3 to 5 and chroma 3 to4.
	Bhimanahalli (BHI) Series: Bhimanahalli soils are shallow (25-50 cm), well drained, have very dark gray to brown clay soils. They have developed from basalt and occur on very gently sloping to gently sloping uplands. The thickness of the solum ranges from 29 to 48 cm. The thickness of A horizon ranges from 15 to 20 cm. Its colour is in 7.5 YR and 10 YR hue with value 3 to 4 and chroma 2 to 4. The thickness of B horizon ranges from 23 to 33 cm. Its colour is in 10 YR and 7.5 YR hue with value 3 to 4 and chroma 1 to 3.
	Kalamundargi (KGI) Series: Kalamundargi soils are shallow (25-50 cm), well drained, have very dark grayish brown to dark brown gravelly clay soils. They have developed from basalt and occur on very gently sloping uplands. The thickness of the solum ranges from 26 to 48 cm. The thickness of A horizon ranges from 10 to 19 cm. Its colour is in 7.5 YR and 10 YR hue with value 3 to 4 and chroma 2 to 4. The thickness of B horizon ranges from 26 to 37 cm. Its colour is in 10 YR and 7.5 YR hue with value 3 to 4 and chroma 2 to4.
	Novinihala (NHA) Series: Novinihala soils are shallow (25-50 cm), well drained, have very dark grayish brown to dark brown clay soils. They have developed from basalt and occur on very gently to gently sloping uplands. The thickness of A horizon ranges from 12 to 20 cm. Its colour is in 7.5 YR and 10 YR hue with value 3 to 4 and chroma 2 to 4. The thickness of B horizon ranges from 32 to 45 cm. Its colour is in 10 YR and 7.5 YR hue with value 3 to 4 and chroma 2 to 4.
	Gutti (GTT) Series: Gutti soils are moderately shallow (50-75cm), moderately well drained, have very dark gray to brown clayey soils. They have developed from basalt and occur on very gently sloping uplands. The thickness of the solum ranges from 24 to 74 cm. The thickness of A horizon ranges from 7 to 23 cm. Its colour is in 10 YR and 7.5 YR hue with value 3 to 4 and chroma 2 to 3. The thickness of B horizon ranges from 28 to 65 cm. Its colour is in 10 YR and 7.5 YR hue with value 3 to 4 and chroma 2 to 3.
	Kamalapur (KMP) Series: Kamalapur soils are moderately deep (75-100 cm), moderately well drained, have very dark gray to very dark grayish brown cracking clay soils. They have developed from basalt and occur on very gently sloping uplands. The thickness of the solum ranges from 75 to 95 cm. The thickness of A horizon ranges from 10 to 30 cm. Its colour is in 10 YR and 7.5 YR hue with value 3 to 4 and chroma 1 to 4. The thickness of B horizon ranges from 45 to 84 cm. Its colour is in 10 YR hue with value 3 to 4 and chroma 1 to 4. The available water capacity is medium (101-150 mm/m).
	Rajanala (RNL) Series: Rajanala soils are deep (100-150 cm), moderately well drained, have very dark gray to brown cracking clay soils. They have developed from basalt and occur on very gently to gently sloping uplands. The thickness of the solum ranges from 125 to 140 cm. The thickness of A horizon ranges from 14 to 23 cm. Its colour is in 10 YR hue with value 3 to 4 and chroma 1 to 2. The thickness of B horizon ranges from 85 to 130 cm. Its colour is in 10 YR hue with value 3 to 4 and chroma 1 to 3.

Table-2 Soil depth, soil slope and soil erosion of the study area

Class	Soil mapping units	Area in ha (%)
	Soil depth	
Very shallow (<25 cm)	1- MGTiB2g2, 2-MGTiC3g3, 3-MGTiD3g3, 4-MGTmA1, 5-MGTmB1, 6-MGTmB1g1, 7- MGTmB1g2, 8-MGTmB2g1, 9-MGTmB2g2, 10-MGTmC3g1, 11-MGTmC3g2, 12-MGTmC3g3	265 (38.67)
Shallow (25-50 cm)	13-BHImB1, 14-BHImB1g1, 15-BHImB1g2, 16-KGImB2g2, 17-NHAmB1g1, 18-NHAmB2g1	217 (31.64)
Moderately Shallow (50-75 cm)	19-GTTmB1, 20-GTTmB1g1, 21-GTTmB2	62 (9.03)
Moderately deep (75-100 cm)	22-KMPmB1, 23-KMPmB1g1	26 (3.74)
Deep (100-150 cm)	24- RNLmB1	89 (12.99)
	Soil gravelliness	
Non-gravelly (<15%)	4-MGTmA1, 5-MGTmB1, 13-BHImB1, 19-GTTmB1, , 21-GTTmB2, 22-KMPmB1, 24-RNLmB1	241 (35.1)
Gravelly (15-35%)	6-MGTmB1g1, 8-MGTmB2g1, 10-MGTmC3g1, 14-BHImB1g1, 17-NHAmB1g1, 18-NHAmB2g1, 20-GTTmB1g1, 23-KMPmB1g1	266 (38.79)
Very gravelly (35-60%)	1-MGTiB2g2, 7-MGTmB1g2,9-MGTmB2g2, 11-MGTmC3g2, 15-BHImB1g2, 16-KGImB2g2	103 (15.01)
Extremely gravelly (60-80%)	2-MGTiC3g3, 3-MGTiD3g3, 12-MGTmC3g3	49 (7.18)
	Soil erosion	
Slight	1-MGTiB2g2,4-MGTmA1,5-MGTmB1,6-MGTmB1g1,7-MGTmB1g2,13-BHImB1,14- BHImB1g1,15-BHImB1g2,17-NHAmB1g1,18-NHAmB2g1,19-GTTmB1,20-GTTmB1g1, 22-KMPmB1, 23-KMPmB1g1, 24- RNLmB1	472 (68.78)
Moderate	8-MGTmB2g1, 9-MGTmB2g2, 16-KGImB2g2, 21-GTTmB2	118 (17.15)
Severe	2-MGTiC3g3, 3-MGTiD3g3, 10-MGTmC3g1, 11-MGTmC3g2, 12-MGTmC3g3	70 (10.15)
	Soil slope	
Nearly level (0-1%)	4-MGTmA1	8 (1.14)
Very gently sloping (1-3%)	1-MGTiB2g2,5-MGTmB1,6-MGTmB1g1,7-MGTmB1g2,8-MGTmB2g1,9-MGTmB2g2,13- BHImB1,14-BHImB1g1,15-BHImB1g2,16-KGImB2g2,17-NHAmB1g1,18-NHAmB2g1,19-GTTmB1, 20-GTTmB1g1, 21-GTTmB2, 22-KMPmB1, 23-KMPmB1g1, 24- RNLmB1	582 (84.79)
Gently sloping (3-5%)	2-MGTiC3g3, 10-MGTmC3g1, 11-MGTmC3g2, 12-MGTmC3g3	55 (8.07)
Moderately sloping (5-10%)	3-MGTiD3g3	14 (2.08)
	Surface soil texture	
Sandy clay	1- MGTiB2g2, 2-MGTiC3g3, 3-MGTiD3g3	36 (5.23)
Clay	4-MGTmA1,5-MGTmB1,6-MGTmB1g1,7-MGTmB1g2,8-MGTmB2g1,9-MGTmB2g2,10- MGTmC3g1, 11-MGTmC3g2, 12-MGTmC3g3, 13-BHImB1, 14-BHImB1g1, 15-BHImB1g2, 16-KGImB2g2,17-NHAmB1g1,18-NHAmB2g1,19-GTTmB1,20-GTTmB1g1,21-GTTmB2, 22-KMPmB1, 23-KMPmB1g1, 24- RNLmB1	624 (90.85)
	Available water capacity	
Very low (<50 mm/m)	1- MGTiB2g2, 2-MGTiC3g3, 3-MGTiD3g3, 4-MGTmA1, 5-MGTmB1, 6-MGTmB1g1, 7-MGTmB1g2, 8-MGTmB2g1, 9-MGTmB2g2, 10-MGTmC3g1, 11-MGTmC3g2, 12- MGTmC3g3, 13-BHImB1, 14-BHImB1g1, 15-BHImB1g2, 16-KGImB2g2	446 (64.96)
Low (51-100 mm/m)	17-NHAmB1g1, 18-NHAmB2g1, 19-GTTmB1, 20-GTTmB1g1, 21-GTTmB2,	99 (14.38)
Medium (101-150 mm/m)	22-KMPmB1, 23-KMPmB1g1	26 (3.74)
Very high (>200 mm/m)	24- RNLmB1	89 (12.99)

Table-3 Soil properties of different soil series of the study area

Soil series		pH	EC dS/m	OC (%)	P_2O_5 (Kg/ha)	K_2O (Kg/ha)	S ppm	B ppm	Cu ppm	Fe ppm	Mn ppm	Zn ppm
Margutti (MGT)	Mean	7.60	0.21	0.73	19.95	427.17	10.83	0.40	4.31	13.11	31.97	0.60
	Std	0.57	0.09	0.18	57.41	226.63	6.35	0.22	1.91	6.87	23.95	0.27
	CV%	7.54	41.61	24.70	287.71	53.05	58.61	54.39	44.39	52.43	74.90	44.45
Bhimanahalli (BHI)	Mean	7.77	0.22	0.66	12.12	381.13	12.30	0.41	4.14	11.50	26.60	0.59
	Std	0.53	0.09	0.14	11.67	195.00	8.21	0.23	1.30	4.99	22.21	0.26
	CV%	6.83	40.88	21.49	96.28	51.16	66.71	55.12	31.49	43.38	83.50	44.14
Kalamundargi (KGI)	Mean	7.79	0.23	0.58	44.66	301.85	12.50	0.42	3.75	9.72	16.36	0.48
	Std	0.49	0.09	0.15	63.50	84.39	6.12	0.21	0.62	4.14	7.51	0.19
	CV%	6.35	41.41	25.50	142.21	27.96	48.95	50.10	16.42	42.59	45.92	39.40
Novinihala (NHA)	Mean	7.76	0.16	0.62	7.10	187.02	4.18	0.30	4.42	12.26	653.38	0.42
	Std	0.34	0.06	0.06	6.60	36.14	2.21	0.22	0.88	3.98	1424.75	0.14
	CV%	4.43	36.20	10.50	92.93	19.33	52.85	72.28	19.97	32.44	218.06	33.09
Gutti (GTT)	Mean	8.28	0.26	0.70	6.20	556.82	10.92	0.44	2.97	6.07	7.99	0.41
	Std	0.30	0.05	0.11	4.12	149.53	5.81	0.13	0.48	1.55	1.70	0.06
	CV%	3.62	21.28	16.12	66.45	26.85	53.23	30.22	16.20	25.52	21.27	14.94
Kamalapur (KMP)	Mean	8.40	0.40	0.85	8.40	792.49	12.57	0.49	5.53	5.39	8.73	0.50
	Std	0.19	0.16	0.09	4.77	94.16	6.83	0.20	1.92	1.36	1.91	0.11
	CV%	2.27	39.61	10.26	56.77	11.88	54.34	41.57	34.68	25.20	21.85	21.17
Rajanala (RNL)	Mean	8.35	0.31	0.71	8.47	581.24	9.07	0.40	3.30	6.28	7.80	0.41
	Std	0.16	0.13	0.14	6.41	158.37	3.94	0.13	0.49	4.79	1.72	0.15
	CV%	1.94	41.40	19.43	75.70	27.25	43.44	34.09	14.78	76.34	22.10	37.06

Table-4 Crop suitability criteria for two major crops in Matki-3 microwatershed

Crop requirement		Rating			
		Pigeon pea			
Soil-site characteristics	unit	Highly suitable (S1)	Moderately Suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Slope	%	<3	3-5	5-10	>10
LGP	Days	>210	180-210	150-180	<150
Soil drainage	class	Well drained	Mod. to well drained	Imperfectly drained	Poorly drained
Soil reaction	pH	6.5-7.5	5.0-6.5 7.6-8.0	8.0-9.0	>9.0
Surface soil texture	Class	l, scl, sil, cl, sl	sicl, sic, c(m)	ls	S, fragmental
Soil depth	Cm	>100	85-100	40-85	<40
Gravel content	% vol.	<20	20-35	35-60	>60
Salinity (EC)	dS m^{-1}	<1.0	1.0-2.0	>2.0	-
Sodicity (ESP)	%	<10	10-15	>15	-
		Sorghum			
Slope	%	2-3	3-8	8-15	>15
LGP	Days	120-150	120-90	<90	
Soil drainage	class	Well to mod. drained	imperfect	Poorly/excessively	V. poorly
Soil reaction	pH	6.0-8.0	5.5-5.9 8.1-8.5	<5.5 8.6-9.0	>9.0
Surface soil texture	Class	C, cl, sicl, sc	l, sil, sic	Sl, ls	S, fragmental skeletal
Soil depth	Cm	100-75	50-75	30-50	<30
Gravel content	% vol.	5-15	15-30	30-60	>60
Salinity (EC)	dS m^{-1}	2-4	4-8	8-10	>10
Sodicity (ESP)	%	5-8	8-10	10-15	>15

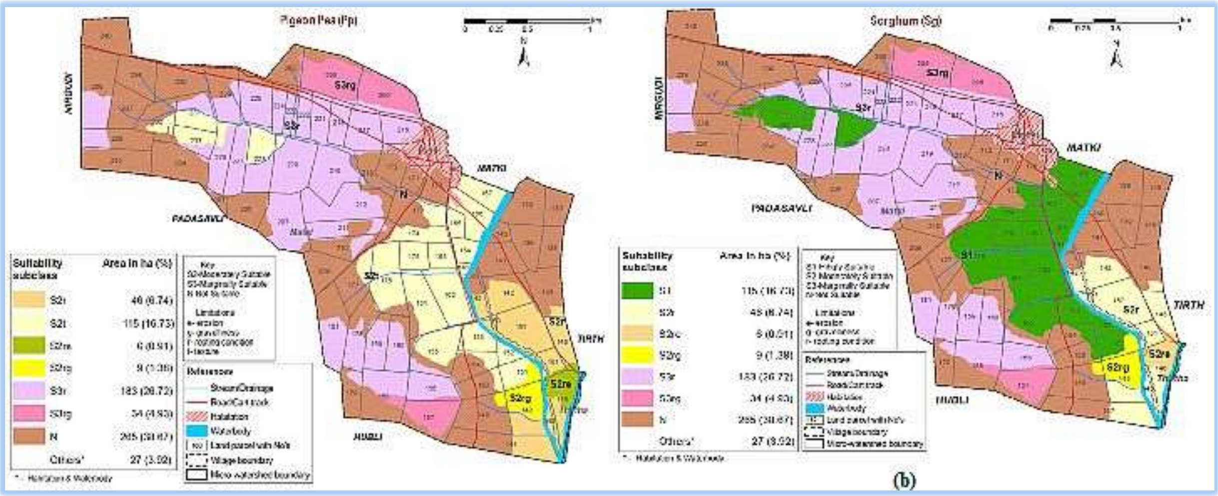

Fig-6 (a). Land suitability map of Pigeon pea (*Cajanus cajan*) and (b) Sorghum (*Sorghum bicolor*)

December to 232 mm in the month of May. The PET is always higher than precipitation in all the months except August and September. Generally, the length of crop growing period (LGP) is 150 days and starts from 3rd week of June to 3rd week of November. It is reported that, low rainfall epochs return at a periodicity of 17 years at Bijapur and at 13 years at Dharward. The results further said that the return of such events co-existed at both places during the present and episode. Similar analysis at other stations may also indicate the wide spread nature of the last epoch of low rainfall at all places [34]. It is deduced from the report of [35], Gulbarga, has very low values of water resource vulnerability index (WRVI) and therefore belong to the category of very high vulnerability (cluster 4) due to low availability of surface water, high crop water stress, and exposure to flood and drought. The water balance diagram shows that the length of growing period is 120 to 150 days with erratic rainfall and prolonged dry spells during crop season and made to choose locally adopted dryland sorghum and pigeon pea.

Current land use

Major crops grown in the Matki-3 microwatershed revealed that pigeon pea (*Cajanus cajan*) and sorghum (*Sorghum bicolor*) are the principal crops. The current land use of Matki-3 microwatershed [Fig-5] with respect to 24 soil mapping units shows that about 80% area under cultivation of pigeon pea, out of that pigeon pea with sorghum multicropping cultivation was adapted mostly in all mapping units *viz.*, except few areas of MGTiD3g3 and MGTmB1.

Biophysical constraints

The seven biophysical constraints for pigeon pea and sorghum are considered under this study and reported area under each constraints of each soil mapping unit in [Table-2]. The microwatershed under study has 39% of total under very shallow; 85% area under very gently slopes and 27% under moderate to severe erosion (50%). About 22% area has very gravelly to extremely gravelly with 91% of area under clay texture. About 65% soils are affected by very low (<50 mm/m) available water capacity [Table-2].

Fertility status of soils

The chemical properties of seven soil series with 24 soil mapping units are given in [Table-3]. Soil pH is slightly alkaline in NHA and MGT; moderately alkaline for MGT, BHI, KGI, NHA, GTT, KMP and RNL; and neutral in small area of MGT and BHI soil series. All these soils have low salt concentration with EC less than 0.2 dS m^{-1}. Kamalapur soil series (KMP) have high organic carbon with mean of 0.85±0.09 with a variation of 10.26 per cent (least variable).

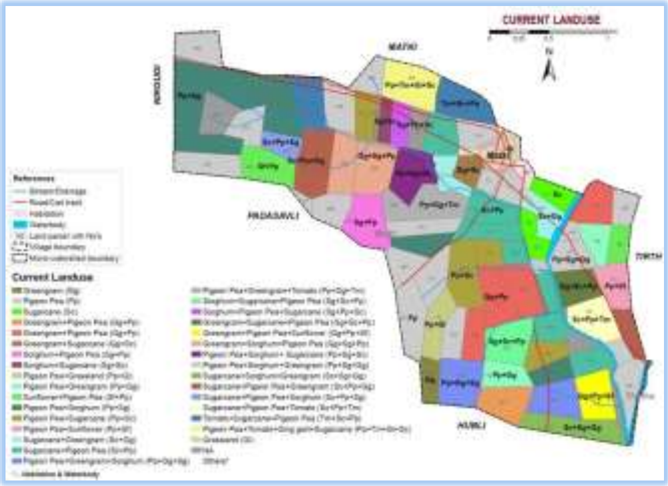

Fig-5 Current landuse map of the study area Matki-3 Microwatershed

Similar kind of least variability of soil organic carbon is recorded in Novinihala soil series (10.50%) whereas moderate variation of organic carbon with CV of 16 to 25% in case of Gutti, Rajanala, Bhimanahalli, Margutti and Kalamundargi soil series. Available phosphorous was low except Kalamundargi series. Available potassium was high in MGT, BHI, GTT, KMP and RNL and medium in KGI and NHA with moderate CV% (<35%), [36] in all soil series under study. Similar trends of low status of available sulphur are recorded Novinihala and Rajanala and available boron was recorded in all soil series with high percent of variability CV>35%. The mean values of micronutrients (Cu, Fe, Mn and Zn) are sufficient to high [24] with moderate to higher CV%, except in Zn under all seven soil series respectively. Cu with high CV% (>35%) in MGT and Fe in MGT, BHI, KGI and RNL soil series. but for Mn and Zn, moderate CV% (<35%) observed under Novinihala, Gutti, Kamalapur and Rajanala soil series.

Table-5 Land suitability for various crops of the study area (Matki-3 Microwatershed)

Crops	Highly suitable(S1)	Moderately suitable (S2)	Marginally suitable (S3)
	Suitability Area in ha (%)		
Pigeon pea (*Cajanus cajan*)	-	176 ha (26%)	217 ha (32%)
Sorghum (*Sorghum bicolor*)	115 ha (17%)	61 ha (9%)	217 ha (32%)

Crop suitability maps with area

Using the criteria in [Table-4], the soil map units of the microwatershed are evaluated and land suitability maps for 2 major crops are generated [Fig-6a] and [Fig-6b]. The crop requirements for growing pigeon pea (*Cajanus cajan*) [Table-4] were matched with the soil-site characteristics of the soils of the microwatershed and land suitability map for growing pigeon pea was generated. An area of about 176 ha (26%) is moderately suitable (S2) for pigeon pea and are distributed dominantly in the southwestern, central, northeastern and southeastern part of the microwatershed [Table-5]. They have minor limitations of texture, rooting depth, gravelliness and erosion. An area of about 217 ha (32%) is marginally suitable (S3) and are distributed in the southern and northwestern part of the microwatershed [Fig-6a]. They have moderate limitations of depth of rooting and gravelliness. Majority of area of about 265 ha (39%) is not suitable (N) for growing pigeon pea and distributed in all parts of the microwatershed. In case of pigeon pea, it is suggested to sow early to obtain higher yields and also give one or two protective irrigations in the event of dry spells during crop season. The length of growing period is in support of pigeon pea cultivation in the areas rainfall exceeds half PET from the mid week of July and then extends upto mid week of October. The crop requirements for growing sorghum (*Sorghum bicolor*) [Table-4] are matched with the soil-site suitability. About 115 ha (17%) areas are highly suitable (S1) for growing sorghum with no limitations and are distributed mainly in the central and northwestern part of the microwatershed [Fig-6b]. Whereas 61 ha (9%) is moderately suitable (S2) distributed in the southeastern part with minor limitations of gravelliness, erosion and rooting depth and 217 ha (32%) marginally suitable lands (S3) concentrated in the south, west and northern part of the microwaterhsed with moderate limitations of rooting depth and gravelliness [Table-5]. About 265 ha (39%) is not suitable (N) for growing sorghum and are distributed in all parts of the microwatershed. They are grown under limited irrigation sorghum usually grown in dry land areas with soils less than 15 cm deep, using farmyard manures and household produced biofertilisers [38]. Short duration varieties are grown with duration of 65 days. They are mainly grown by small and marginal farmers (*i.e.*, those with farm size less than 5 hectares) [39]. It is hereby suggested to modify the depth criteria in land evaluation exercises for sorghum to bring marginal areas under cultivation in the watershed. This is possible with the crop interventions suggested to enhance productivity of sorghum by organizing on farm demonstration trials with the integration of package of practices involving moisture conservation, integrated nutrient management, and improved varieties and by popularizing the "seed village" programme through gram panchayats.

Conclusion

The land resource information obtained from detailed soil survey shows that this micro watershed has seven soil series belongs to the subgroups of vertisols and vertic integrates having low available sulphur and boron with wide spread phosphorus, Zn deficiency. The soil map with twenty four mapping units was used in land evaluation for pigeon pea and sorghum. The results showed that 58% of total for Pigeon pea and sorghum is evaluated as suitable with limitations of soil depth, gravelliness and slope. To enhance productivity, it is suggested to go for early sowing of pigeon pea with supplementary irrigation in times of dry spells but for sorghum, soil-water conservation measures must be integrated with nutrient management.

Application of research: From this study, it shows land suitability analysis for agricultural crops using land evaluation in a GIS environment is a strong tool for measuring and evaluating land in terms of the varying importance to decision makers for sustainable rainfed agriculture.

Research Category Soil Land Use

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