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Soil suitability assessment for sustainable production of Cereals in Kanamadi South Subwatershed

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Abstract
A soil suitability evaluation of Kanamadi South sub-watershed in the Northern Dry Zone of India was undertaken in the present study to define the soil fitness for the production of maize, pearl millet, and sorghum, the three major kinds of cereal that are widely grown in the area. The soils of Kanamadi south sub watershed were grouped into 19 mapping units. The mapping units of the study area were moderately (S2) to marginally suitable (S3) for maize. The suitability of the study area for pearl millet was found to be highly suitable (S1) to marginal (S3) suitable for pearl millet. The mapping units of the study area were high to marginally suitable for growing sorghum. Appropriate soil fertility management recommendations through an integrated soil fertility management approach should be applied to address these limitations as their lack of attention could affect the availability and uptake of nutrients by these crops in the study area.

Keywords: Kanamadi South sub-watershed, mapping unit, marginally suitable, moderately suitable

Introduction
Land suitability assessment is a prerequisite to achieving optimum utilization of available land resources for agricultural production in a sustainable manner. FAO (1976) [5] defined land suitability as 'a function of crop requirements and land characteristics as well as a measure of how well the qualities of a land unit matches the requirements of a particular form of land use'. Land suitability assessment allows identifying the main limiting factors of a piece of land for particular crop production and enables decision-makers to develop a crop management system for increasing land productivity. (Denis *et al*., 2016) [4].

Information on soil and related properties obtained from the soil survey and soil classification can help in better delineation of soil suitability for crops. The performance of any crop is largely dependent on soil properties such as depth, drainage, texture, etc., as conditioned by climate and topography (Bargali *et al.,* 1993) [3]. The study of the soil-site characterization for predicting the crop performance of an area forms a part of the land evaluation process (Arora *et al.,* 2011) [2]. According to FAO (1976) [5], land evaluation is the rating of soil for optimum returns per unit area. The yield influencing factors for important crops have to be evaluated and the results obtained may be applied for higher production of these crops through proper utilization of similar soils occurring elsewhere in similar agro-climate sub-region under scientific management practices (Khadse and Gaikwad, 1995) [6]. Information on soil-site suitability evaluation for maize, pearl millet, and sorghum is not available for the study area. The present study was therefore undertaken to unfold this information.

Kanamadi south subwatershed is located 39.2 km away from Vijayapura (Bijapur), headquarter town of Vijayapura District. This area lies in the Northern dry zone of Karnataka and has a hot arid ecosystem with hot and dry summers and mild winters (K4D2) and sub-region 6.1 (K4Dd3) North Karnataka Plateau. Kanamadi South Subwatershed (Vijayapura taluk, Vijayapura district) is located in between 16° 51' - 16° 55' 30" North latitudes and 75° 21' -75° 26' 30" East longitudes, covering an area of about 4170.17 ha, bounded by Kanamadi on the North, Bijjaragi on the East, Honawada on the South and Belagavi district on the West. The area receives an annual average rainfall of 711 mm distributed over May to October.

Material and Methods

Soil Survey

A detailed soil survey of the Kanamadi south sub-watershed was carried out using IRS P6 LISS-IV image and Vijayapura district Toposheet. The image and scanned Toposheet were geocoded and a subset was created in ArcGIS 10.2 on a 1: 12,500 scale. The area was then intensively traversed and 19 pedon locations were fixed on soil heterogeneity. At each pedon location, a fresh profile was opened and detailed morphological studies as described by the USDA Soil Survey Manual (2000) [11] and horizon-wise samples were collected and analyzed for Physico-chemical parameters.

Soil Mapping

Based on soil heterogeneity as revealed by laboratory analysis and visual interpretation of the IRS P6 LISS-IV image, soil mapping units were delineated following the USDA Soil Survey manual (2000) [11] and evaluated for the land capability and soil site suitability for crops.

Soil Site Suitability evaluation for crops

The FAO (1976) [5] framework for land evaluation was followed in the evaluation of soil-site suitability for maize, pearl millet and sorghum in the Kanamadi south sub-watershed. This classification recognizes two orders of land suitability, order 'S' (suitable) and order 'N' (not suitable) which are further subdivided into land suitability classes.

The classification includes four categories: orders, classes, subclasses, and units. There are two orders (S, N) that reflect the kind of suitability (S for suitable and N for unsuitable). There are three classes (S-1 to 3) under the suitable order S and two classes (N-1 and 2) under the order N, reflecting the degree of suitability within the order. The appraisal of the classes, within an order, is done according to the evaluation of land limitations. The subclasses reflect the kinds of limitations or the main kinds of improvement measures required within a class. They are indicated by the symbol, using lower case letters following the arabic numeral used for the class. The land suitability unit suggests the relative importance of land improvement works. It is indicated by arabic numerals enclosed in parenthesis following the subclass symbol. The criteria for evaluation of soil suitability for maize, pearl millet, and sorghum are given in tables 1, 2 and 3.

Table 1: Soil site suitability criteria (crop requirements) for Maize

Soil site characteristics		Rating				
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temperature in growing season	°C	21-32	33-38 15-20	39-40 <15	
	Total rainfall	mm	900-100	750-900	500-750	<500
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	>100	100-80	60-80	
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod. To imperfectly	Poorly/Excessively	V. poorly
Nutrient availability	Texture	Class	l, cl, scl, sil	Sl, sicl, sic (c(n-s)	C (s-s), ls	
	pH	1:2.5	5.5-7.5	7.6-8.5 5.0-5.4	8.6-9.0 <5.0	
	CEC	c mol (p^+) kg^{-1}	>20	15-20	10-15	
	OC	%	High	Medium	Low	
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%	Non gravelly	15-35	35-50	>50
Soil toxicity	Salinity (EC saturation extract)	dS m^{-1}	Non saline	1.0-2.0	2.0-4.0	
	Sodicity (ESP)	%	Non sodic	10-15	>15	
Erosion hazard	Slope	%	<3	3.5	5-8	

***Source*:** Naidu *et al*. (2006) [10].

Table 2: Soil site suitability criteria (crop requirements) for pearl millet

Soil site characteristics			Rating			
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temperature in growing season	°C	28-32	33-38 24-27	39-40 20-23	<20
	Total rainfall	mm	500-750	400-500	200-400	<200
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	>90	70-<90	50-<70	
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Imperfectly drained; poorly drained	
Nutrient availability	Texture	Class	sl, l, scl, sil, cl	ls, c, sicl, sc, c<45	c>45% (SS), s	
	pH	1:2.5	6.0-8.0	5.0-5.9; 8.1-8.5	4.5-4.9; 8.6-9.5	
	$CaCO_3$ in root zone	%	<5	5-10	10-25	>25
	OC	%	0.50-0.75	0.50-0.20	<0.20	
Rooting conditions	Effective soil depth	cm	>75	51-75	25-50	
	Stoniness	%	<15	15-35	>35-50	>50
	Coarse fragments	Vol %				

Soil toxicity	Salinity (EC saturation extract)	dS m^{-1}	<1.0	1.0-2.0	2.0-4.0	
	Sodicity (ESP)	%	<15	15-20	20-35	
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Source: Naidu *et al*. (2006) [10]

Table 3: Soil-site suitability criteria (crop requirements) for sorghum

Soil site characteristics		Rating				
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climatic regime	Mean temp. in growing season	°C	26-30	31-34 24-25	35-40 20-23	>40 <20
	Mean max. temp. in growing season	°C	31-33	33-35	>35	-
	Mean min. temp. in growing season	°C	20-18	18-15	<15	-
	Mean RH in growing season	%	50-70	50-40	<40	-
	Total rainfall	mm	650-850 >850	650-550	450-550	<450
	Rainfall in growing season	mm	500-700	400-500	300-400	<300
Land quality	Land characteristics					
Moisture availability	Length of growing period	Days	120-150	120-90	<90	-
	AWC	mm/m	150-200	100-150	50-100	<50
Oxygen availability to roots	Soil drainage	Class	Well to moderate	Imperfect	Poor and excessive	Very poor
	Water logging in growing season	Days	2-3	3-4	4-5	>5
Nutrient availability	Texture	Class	c, cl, sicl, sc	l, sil, sic	sl, ls	s, fragmental skeletal
	pH	1:2.5	6.0-8.0	5.5-5.9 8.1-8.5	<5.5 8.6-9.0	>9.0
	CEC	c mol (p^+) kg^{-1}	30-20	20-10	<10	
	BS	%	80-50	50-35	<35	
	$CaCO_3$ in root zone	%	5-10	10-25	>25	
	OC	%	0.50-0.75	0.50-0.20	<0.20	
Rooting conditions	Effective soil depth	cm	100-75	50-75	30-60	>30
	Stonnines	%	5-15	15-30	30-60	>60
	Coarse fragments	Vol%	5-15	15-40	40-75	>75
Soil toxicity	Salinity (EC saturation extract)	dS m^{-1}	2-4	4-8	8-10	>10
	Sodicity (ESP)	%	5-8	8-10	10-15	>15
Erosion hazard	Slope	%	2-3	3-8	8-15	>15

***Source*:** Naidu *et al*. (2006) [10]

Table 4: Soil site suitability for cereals in Kanamadi south subwatershed

Mapping units	Maize	Pearl millet	Sorghum
DMTmB2g1	S3s	S3s	S3s
DMTmB2g1Ca	S3s	S3s	S3s
DMTmB2g2Ca	S3s	S3s	S3s
KGRmB2	S2s	S2s	S2s
KGRmB2g1	S2s	S2s	S2s
NHLmB2	S2s	S2s	S2s
THLmB2	S2s	S1	S2s
THLmB2g1Ca	S2s	S1	S2s
THLmB2g2Ca	S2s	S1	S2s
RPRmB2	S2s	S1	S2s
BBLmB2	S2s	S1	S1
NDNmB2	S2s	S2s	S2s
NDNmB2g1Ca	S2s	S2s	S2s
TSLmB2g1Ca	S2s	S2s	S2s
SRDmB2	S2s	S1	S2s
SRDmB2g1Ca	S2s	S1	S2s
KRJmB2	S2s	S2s	S2s
KRJmB2g1Ca	S2s	S2s	S2s
HNTmB2g1Ca	S2s	S1	S1

Results and Discussion

Soil - site suitability for crops

The climate and soil site characteristics play a significant role in maximizing crop yields. The suitability of cereals for each mapping unit was evaluated and results are presented in Table 4. The soil properties of the study area were matched with the soil site suitability criteria for important cereal crops (maize, sorghum and pearl millet) grown in study area.

Maize

The mapping units of the study area were moderately (S2) to marginally suitable (S3) for maize. In general, maize requires an annual rainfall of 900 mm; soil depth of 100 cm with sandy clay loam to clay texture (with 27 – 60 %), and good drainage. All the mapping units were marginally suitable with moderate to severe limitations of rainfall, depth, and organic carbon (Fig. 1).

The mapping unit KGRmB2, KGRmB2g1, NHLmB2, THLmB2, THLmB2g1Ca, THLmB2g2Ca, RPRmB2, BBLmB2 NDNmB2, NDNmB2g1Ca, TSLmB2g1Ca, SRDmB2, SRDmB2g1Ca, KRJmB2, KRJmB2g1Ca, HNTmB2g1Ca were moderately suitable (S2s) with moderate to severe limitation of pH and covered 3640 ha area (87.29 percent) of the sub-watershed area. An area of 482 ha (11.55 % of TGA) was marginally suitable (S3s) had moderate to severe limitation of organic carbon and pH and consists of the mapping unit DMTmB2g1, DMTmB2g1Ca, DMTmB2g2Ca. Similarly, moderate limitations of texture, depth, and drainage have also been reported by Manojkumar (2011) [9] in Bastawad micro-watershed of Northern transition zone of Karnataka and Manjunatha (2015) [8] in Chikmageri micro watershed in Karnataka.

Pearl millet

The suitability of the study area for pearl millet was found to be highly suitable (S1) to marginal (S3) suitable for pearl millet (Fig. 2).

The suitability assessment for pearl millet revealed that the mapping unit HNTmB2g1Ca, BBLmB2, RPRmB2, SRDmB2, SRDmB2g1Ca, THLmB2, THLmB2g1Ca, THLmB2g2Ca were highly suitable (S1) and covered 1923 ha (46.10 % of TGA). The mapping unit KGRmB2, KGRmB2g1, NHLmB2, NDNmB2, NDNmB2g1Ca, TSLmB2g1Ca, KRJmB2, KRJmB2g1Ca were moderately suitable (S2s) had moderate to severe limitation of pH, CaCO3, and organic carbon and covered 1717 ha (41.18 % of TGA). An area of 482 ha (11.55 % of TGA) were marginally suitable S3s with moderate to severe limitation of pH, organic carbon, and CaCO3 which included the mapping unit DMTmB2g1, DMTmB2g1Ca, DMTmB2g2Ca.

It is reported that soil depth of >75 cm, <10 percent CaCO3, and clay texture are favorable for growing pearl millet. Mapping units in the sub-watershed were high to marginally suitable with limitations of soil characteristics for the production of pearl millet. Similar results were also reported by Madhusudan (2019) [7] in the Kanaginahalla subwatershed, which was moderately suitable for pearl millet due to drainage and soil physio-chemical properties.

Sorghum

The mapping units of the study area were high to marginally suitable for growing sorghum (Fig. 3). The soil site suitability assessment for sorghum revealed that 270 ha (6.47 % of TGA) grouped under suitability sub class S1 and covered the mapping unit BBLmB2 and HNTmB2g1Ca. The data showed that 3370 ha (80.82 % TGA) had moderate to marginal limitations of severe limitation of pH, stoniness, soil depth, and organic carbon and grouped as S2s and included the mapping unit KGRmB2, KGRmB2g1, NHLmB2, THLmB2, THLmB2g1Ca, THLmB2g2Ca, RPRmB2, BBLmB2, NDNmB2, NDNmB2g1Ca, TSLmB2g1Ca, SRDmB2, SRDmB2g1Ca, KRJmB2, KRJmB2g1Ca, HNTmB2g1Ca. Whereas, 482 ha (11.55 % of TGA) having marginal to severe limitation of severe limitation of pH, organic carbon, and stoniness and were grouped under the S3s suitability subclass (mapping units DMTmB2g1, DMTmB2g1Ca, DMTmB2g2Ca). It was observed that major constraints limiting sorghum production in the study area were organic carbon, depth, and stoniness. Similar results were reported by Manojkumar (2011) [9]. Anilkumar *et al.* (2019) [1] also reported most of the area of the Haradanahalli micro watershed was moderately suitable (S2) due to limitations of gravelliness, rooting depth, and calcareousness.

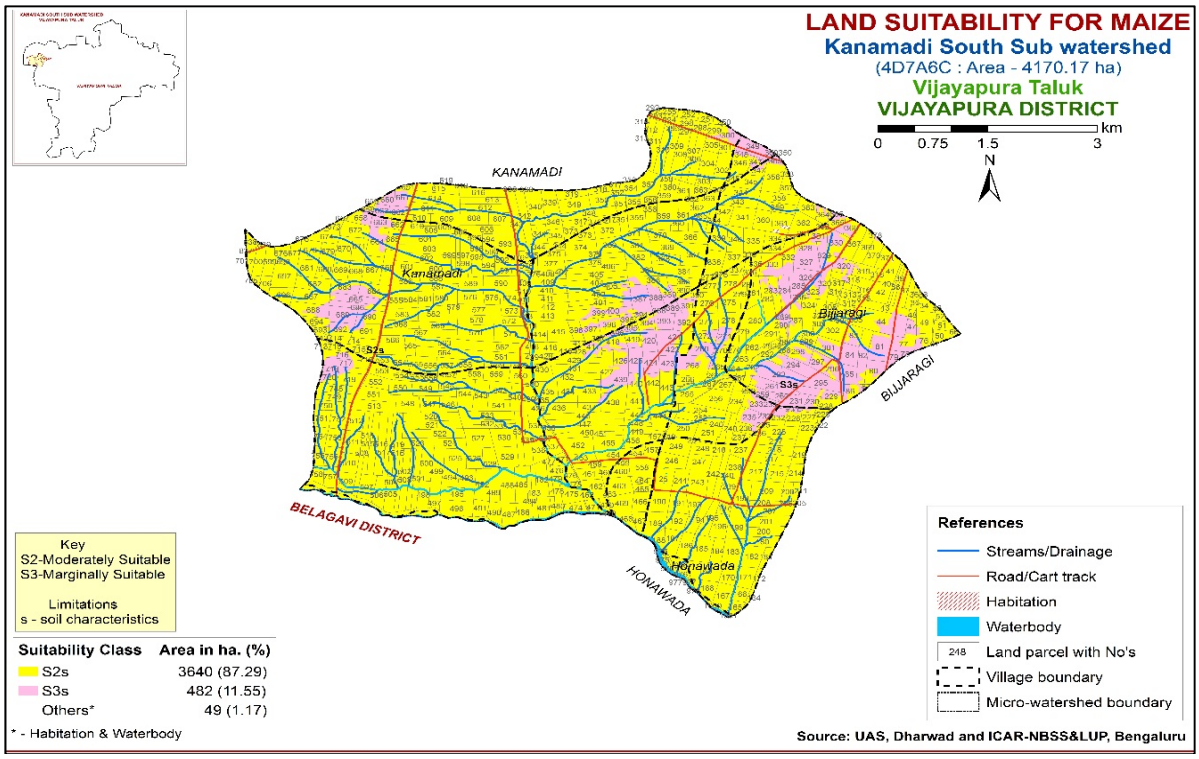

Fig 1: Soil suitability of Kanamadi south sub watershed for Maize

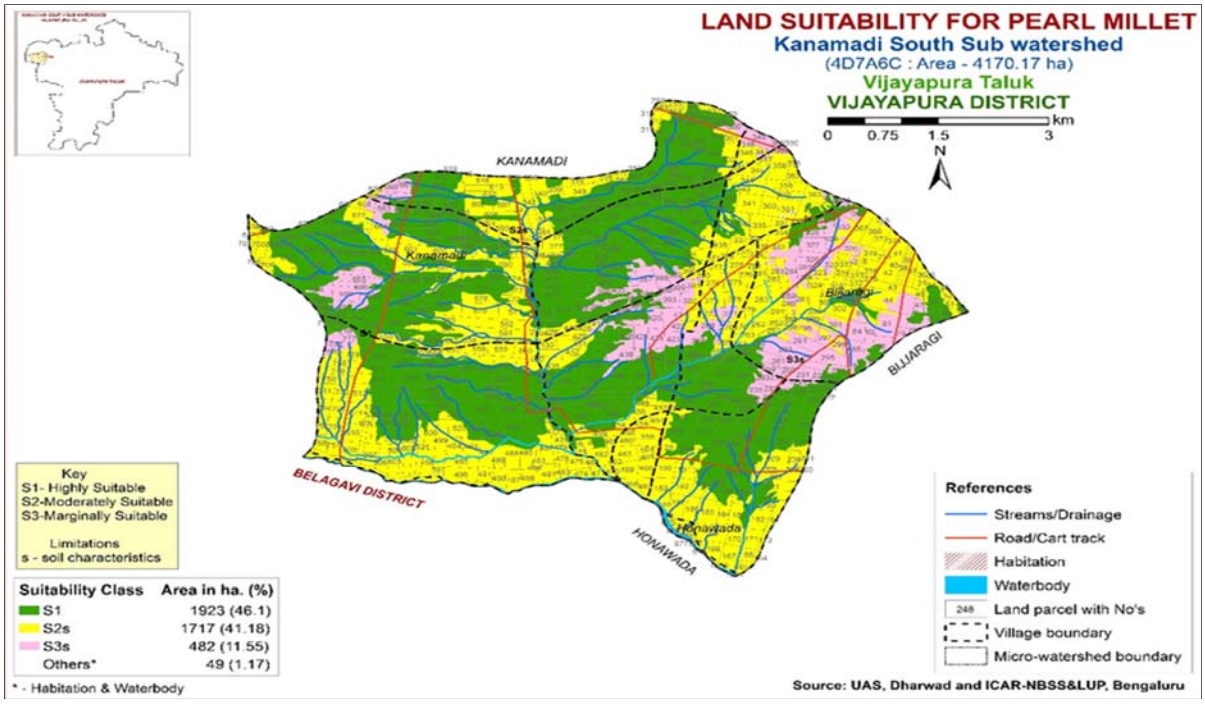

Fig 2: Soil suitability of Kanamadi south sub watershed for pearl millet

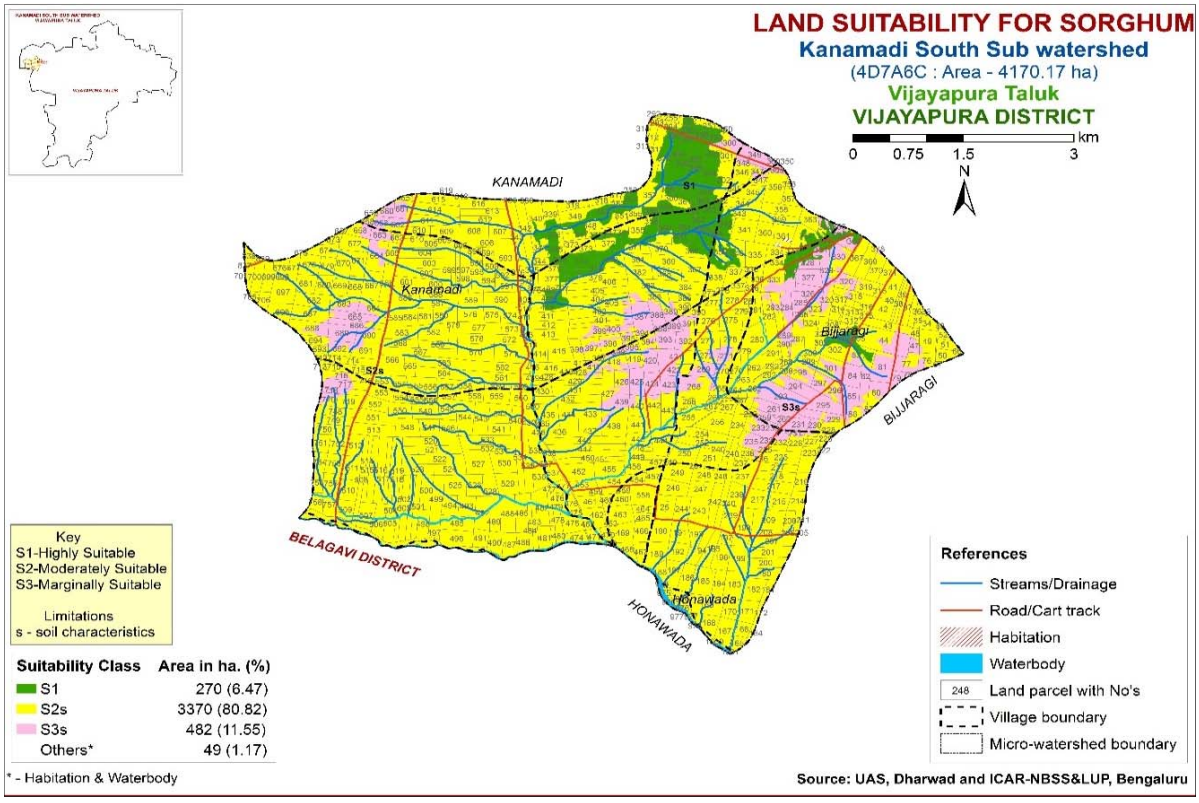

Fig 3: Soil suitability of Kanamadi south sub watershed for sorghum

Conclusions

Based on the soil suitability criteria, the mapping units were evaluated for growing cereal crops in the study area. The suitability evaluation revealed that more than 50 percent of the area was suitable for cereals like maize (S2, 87.29 % TGA), pearl millet (S1+S2, 87.28 % TGA), sorghum (S1+S2, 87.29 % TGA). Soil suitability assessment of cereals helped in identifying the main limiting factors of Kanamadi south subwatershed for cereal crop production and enables decision-makers to develop a crop management system for increasing land productivity.

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The criteria of land capability and soil suitability were followed as per NBSS & LUP guidelines.

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