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Soil-site suitability assessment for major fruit crops in Ganjigatti sub-watershed (5B1A4F), Karnataka using remote sensing and GIS techniques

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Abstract
A study was undertaken to evaluate twenty-one soil series of Ganjigatti sub-watershed of Dharwad district in Northern transition zone (zone-8) of Karnataka for sustainable land use planning. The soil series were AKT (Attikatti), ASR (Adavisomapura), BGD (Bagadgeri), BGH (Bigidigala), BNK (Bhogenagarkoppa), BTP (Bettadapura), GJG (Ganjigatti), HNL (Hirehonnalli), HRG (Harugeri), KDK (Kadanakoppa), KMD (Kamadhenu), KRK (Kuradikeri), MLP (Mahalingpur), MRK (Mishrikoti), MVD (Mevundi), RMN (Ramanala), SDK (Sangedevarakoppa), SGL (Singatalur), SSK (Surashettikoppa), UGK (Ugginakeri) and YSJ (Yelisirur). Based on texture, depth, slope, erosion, graveliness and stoniness, the twenty-one soil series were mapped into sixty-one mapping units by using *Arc*GIS V 10.8. The soil mapping units were evaluated for potential soil site suitability for major fruits crops *viz*., mango, guava, pomegranate, sapota, citrus and grapes. The soil series BGD, BNK, KDK, KMD, KRL, MLP, MRK, SDK, SSK and YSJ were currently not suitable for production of mango, guava, pomegranate, sapota, citrus and grapes due to very severe limitations of soil depth and slope per centage. Whereas; AKT, BGH and MVD series are moderately to marginally suitable for cultivation of these six fruit crops. These results could be used as baseline information for identifying specific soil resource constraints for sustainable production of these crops in the study area.

Keywords: Crop suitability classification, *Arc*GIS, Ganjigatti sub-watershed, fruit crops, soil depth

Introduction
Efficient natural resource management is critical for promising food security and agricultural sustainability. Both scientists and planners place the highest priority on the task of supplying the growing population's food demand without compromising the ecological assets for future generations. In 2050, there would be 9.73 billion people on Earth. Producing 50% more food and feed than in 2012 is necessary for agriculture to keep up with demand by 2050 (FAO, 2017) [7]. At the same time as it has led to the overexploitation and destruction of natural resources like soil, air and water in India, contemporary intensive agriculture is responsible for a quantum rise in crop yield and guarantees food security. Optimal utilisation of soil resources is essential because of the deteriorating state of farmland and the rising need for food. For effective soil management, it is necessary to have a thorough understanding of soil resources (Akpan-Idiok *et al.*, 2016) [1]. Efficient and lasting use of farmland requires first determining whether or not the land is suitable for agriculture. FAO (1976) [8] 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 match the requirements of a particular form of land use'. Land suitability assessment allows for the identification of the main limiting factors of a piece of land for a particular crop production and enables decision-makers to develop a crop management system for increasing land productivity.

For sustainable production and to meet demand from society while protecting fragile ecosystems, it is urgently necessary to link available land resources with present land usage (FAO, 1993) [7]. On the other hand, using geographic information systems (GIS) for the management and analysis of huge amounts of spatial data is necessary for resolving complicated geographical and hydrological issues (Amara *et al.*, 2016) [2]. Large volumes of geographically referenced data gathered from various sources can be collected, managed, analysed and retrieved by users using GIS technology (Aronoff, 1991) [4]. Today, decision support systems, geographic information systems (GIS), and remote sensing (RS) are used to

analyse the suitability of a piece of land. These advanced computer programmes help with the planning process' effectiveness and efficiency and enable quick access to a lot of relevant information. Remote sensing and GIS technologies have drawn a lot of interest, particularly during the past 10 years, in applications relating to land evaluation and resource management on vast spatial dimensions (Green, 1995; Hinton, 1996) [10, 11]. Several studies have already shown the possibility of the integrated strategy to using GIS and RS data for quantitative land evaluation (Ravikumar *et al.*, 2009; Walke *et al.*, 2012; Gangopadhyay *et al.*, 2018) [17, 20, 9]. The present study was undertaken to demonstrate the usefulness of RS and GIS technologies coupled with soil data to assess soil-site suitability for some fruit crops such as mango, guava, pomegranate, sapota, citrus and grapes in the Ganjigatti sub-watershed.

Materials and Methods

The study area

The study was conducted in 2021–2022, in the Ganjigatti sub-watershed (5B1A4F) of Dharwad district in Karnataka, situated between 15° 10′ 10.114″ to 15° 17′ 1.147″ N latitudes and 75° 0′ 57.672″ to 75° 4' 50.525″ E longitudes, with the highest elevation of 610 m above mean sea level. The total geographical area of the watershed is about 4323.84 ha. The annual temperature ranges from 24.68 to 26.67 °C. The average rainfall in the watershed was 917.00 mm (Fig. 1).

Fig 1: Location of the study area

Study method

After preliminary traversing of the entire watershed using a 1:7,920 scale base map and satellite imagery, based on geology, drainage pattern, surface features, slope characteristics, land use, landforms and physiographic divisions, twenty-seven (27) soil profiles were selected and studied and their morphometric characteristics were recorded. Physical and chemical properties were estimated using standard procedures. A detailed soil resource inventory of the Ganjigatti sub- watershed was carried out and 21 soil series mapped into sixty-one (61) mapping units based on surface soil features. After a detailed soil survey, crop suitability maps for major fruit crops growing in the Ganjigatti sub-watershed area at soil phase level were prepared by using the platform of *Arc* GIS V 10.8. Their suitability was assessed using the limitation method regarding the number and intensity of limitations (Naidu *et al.*, 2006) [15]. This evaluation procedure consists of three phases.

In phase I, the data was collected in terms of characteristics as shown in Table 1. The following landscape and soil characteristics were used to evaluate soil suitability: topography (% slope), wetness (flooding and drainage), physical soil characteristics (texture/structure, % coarse fragments by volume, soil depth in cm, CaCO3 per cent), salinity (EC, dSm-1) and alkalinity (ESP). The study locations were nearly level to moderately steep sloping and had never been flooded (F0). The drainage conditions were moderately well to well and sandy loam to clay in texture, as per the guidelines given by FAO (1976) [8]. Soil characteristics were evaluated as suggested by FAO (1976) [8]. In phase II, the landscape and soil requirements for these six crops were taken from Naidu *et al.* (2006) [15] as described by Sehgal (2005) [18].

In phase III, the land suitability under rainfed conditions was assessed by comparing the landscape and soil characteristics with crop requirements at different limitations levels: no (0), slight (1), moderate (2), severe (3), and very severe (4). Limitations are deviations from the optimal conditions of a land characteristic, such as land quality, that adversely affect the kind of land use. If a land characteristic is optimal for plant growth, it has no limitation. On the other hand, when the same characteristic is unfavourable for plant growth, it has severe limitations for land evaluation types. Thus, the evaluation was done by comparing the land characteristics with the limitation levels of the crop requirement given by Naidu *et al*. (2006) [15], as described by Seghal (2005) [21]. The number and degrees of limitations suggested the suitability class of each soil series for a particular crop, as given by FAO (1976) [8].

Table 1: Soil-site characteristics of soil mapping units of Ganjigatti sub-watershed

S. No	Soil Phases	Wetness (w)	Physical condition of Soil (s)					Fertility (f)				Salinity/ alkalinity (n)		Erosion (e)
		Drainage	Texture	Depth (cm)	Stoniness	Gravel	CaCO3%	pH	OC (%)	CEC	BS (%)	EC (dS m-1)	ESP (%)	Slope%
1	AKTmB2R2	Moderately well	clay	79	Nil	<15%	3.21	7.18	0.48	59.33	72.52	0.28	1.48	1-3
2	ASRfB2	Well drained	Clay loam	130	Nil	<15%	15.96	8.68	0.33	48.7	87.46	0.36	1.00	1-3
3	ASRfB2g1	Well drained	Clay loam	130	Nil	15-35%	15.96	8.68	0.33	48.7	87.46	0.36	1.00	1-3
4	ASRmB2	Well drained	Clay	130	Nil	<15%	15.96	8.68	0.33	48.7	87.46	0.36	1.00	1-3
5	ASRmC3	Well drained	Clay	130	Nil	<15%	15.96	8.68	0.33	48.7	87.46	0.36	1.00	3-5
6	BGDhB2g1	Well drained	Sandy clay loam	20	Nil	15-35%	1.5	5.91	1.19	16.55	60.76	0.49	1.94	1-3
7	BGDhC3g2	Well drained	Sandy clay loam	20	Nil	35-60%	1.5	5.91	1.19	16.55	60.76	0.49	1.94	3-5
8	BGHfB2	Moderately well	Clay loam	90	Nil	<15%	7.35	7.33	0.6	23.64	85.7	0.3	2.19	1-3
9	BGHfB2g1	Moderately well	Clay loam	90	Nil	15-35%	7.35	7.33	0.6	23.64	85.7	0.3	2.19	1-3
10	BGHfB2g2	Moderately well	Clay loam	90	Nil	35-60%	7.35	7.33	0.6	23.64	85.7	0.3	2.19	1-3
11	BGHfC3	Moderately well	Clay loam	90	Nil	<15%	7.35	7.33	0.6	23.64	85.7	0.3	2.19	3-5
12	BGHfC3g1	Moderately well	Clay loam	90	Nil	15-35%	2.99	7.08	0.58	23.48	83.88	0.12	1.72	3-5
13	BGHfD3g2	Moderately well	Clay loam	90	Nil	35-60%	2.99	7.08	0.58	23.48	83.88	0.12	1.72	5-10
14	BGHhB2	Moderately well	Sandy clay loam	90	Nil	<15%	7.35	7.33	0.6	23.64	85.7	0.3	2.19	1-3
15	BGHhB2g1	Moderately well	Sandy clay loam	90	Nil	15-35%	7.35	7.33	0.6	23.64	85.7	0.3	2.19	1-3
16	BGHmB1g1St2	Moderately well	Clay	80	1-3	15-35%	3.5	6.83	0.83	43.84	77.7	0.18	0.53	1-3

Table 1. Contd…..

S. No	Soil Phases	Wetness (w)	Physical condition of Soil (s)					Fertility (f)				Salinity/ alkalinity (n)		Erosion (e)
		Drainage	Texture	Depth (cm)	Stoniness	Gravel	CaCO3%	pH	OC (%)	CEC	BS (%)	EC (dS m-1)	ESP (%)	Slope%
17	BNKmB1	Well drained	Clay	35	Nil	<15%	2.81	7.23	0.53	28.34	69.91	0.22	2.42	1-3
18	BNKmB1g1	Well drained	Clay	35	Nil	15-35%	2.81	7.23	0.53	28.34	69.91	0.22	2.42	1-3
19	BNKmB2g1	Well drained	Clay	35	Nil	15-35%	2.81	7.23	0.53	28.34	69.91	0.22	2.42	1-3
20	BNKmC2g2	Well drained	Clay	35	Nil	35-60%	2.81	7.23	0.53	28.34	69.91	0.22	2.42	3-5
21	BTPmA1	Well drained	Clay	200	Nil	<15%	12.02	8.3	0.75	58.22	90.28	0.16	2.67	0-1
22	BTPmB2	Well drained	Clay	200	Nil	<15%	12.02	8.3	0.75	58.22	90.28	0.16	2.67	1-3
23	BTPmB2g1	Well drained	Clay	180	Nil	15-35%	13.28	7.82	0.45	37.39	89.51	0.36	2.63	1-3
24	GJGiB2	Moderately well	Sandy Clay	55	Nil	<15%	3.76	7.22	0.66	22.68	71.53	0.22	1.48	1-3
25	GJGiB2g1	Moderately well	Sandy Clay	55	Nil	15-35%	3.76	7.22	0.66	22.68	71.53	0.22	1.48	1-3
26	GJGiC3g1	Moderately well	Sandy Clay	55	Nil	15-35%	3.76	7.22	0.66	22.68	71.53	0.22	1.48	3-5
27	HNLiC2g1	Moderately well	Sandy Clay	67	Nil	15-35%	3.06	5.92	0.66	19.82	50.72	0.26	2.03	3-5
28	HNLiC2g2	Moderately well	Sandy Clay	67	Nil	35-60%	3.06	5.92	0.66	19.82	50.72	0.26	2.03	3-5
29	HRGmB2	Moderately well	Clay	130	Nil	<15%	15.9	8.1	0.49	49.58	90.85	0.34	0.86	1-3
30	HRGmB2Ca	Moderately well	Clay	130	Nil	<15%	15.9	8.1	0.49	49.58	90.85	0.34	0.86	1-3
31	HRGmC3g1	Moderately well	Clay	130	Nil	15-35%	15.9	8.1	0.49	49.58	90.85	0.34	0.86	3-5
32	KDKhB2g1	Moderately well	Sandy Clay loam	49	Nil	15-35%	2.89	6.42	0.53	59.33	72.52	0.16	0.84	1-3
33	KDKhC3g2	Moderately well	Sandy Clay loam	49	Nil	35-60%	2.89	6.42	0.53	59.33	72.52	0.16	0.84	3-5
34	KDKhC3g3	Moderately well	Sandy Clay loam	49	Nil	60-80%	2.89	6.42	0.53	59.33	72.52	0.16	0.84	3-5

Table 1. Contd…..

S. No	Soil Phases	Wetness (w)	Physical condition of Soil (s)					Fertility (f)				Salinity/alkalinity (n)		Erosion (e)
		Drainage	Texture	Depth (cm)	Stoniness	Gravel	CaCO 3%	pH	OC (%)	CEC	BS (%)	EC (dS m-1)	ESP (%)	Slope%
35	KDKiB2	Well drained	Clay loam	35	Nil	<15%	2.53	6.84	0.76	23	69.1	0.22	1.87	1-3
36	KMDhC3g2	Well drained	Sandy Clay loam	35	Nil	35-60%	0.91	5.36	0.73	11.15	49.67	0.1	1.82	3-5
37	KMDmB2	Well drained	Clay	35	Nil	<15%	0.91	5.36	0.73	11.15	49.67	0.1	1.82	1-3
38	KMDmB2g1	Well drained	Clay	35	Nil	15-35%	0.91	5.36	0.73	11.15	49.67	0.1	1.82	1-3
39	KRKfC2g1	Well drained	Clay loam	30	Nil	15-35%	2.65	5.61	0.58	20.03	68.16	0.09	2.07	3-5
40	KRKmC2g1	Well drained	Clay	40	Nil	15-35%	3.33	6.02	1.02	21.16	70.31	0.06	0.79	3-5
41	MLPdB1g1	Moderately well	Loam	20	Nil	15-35%	1.35	5.83	0.58	23.62	49.72	0.11	2.22	1-3
42	MLPdC2g1	Moderately well	Loam	20	Nil	15-35%	1.35	5.83	0.58	23.62	49.72	0.11	2.22	3-5
43	MLPdC2g2	Moderately well	Loam	20	Nil	35-60%	1.35	5.83	0.58	23.62	49.72	0.11	2.22	3-5
44	MRKiB2	Moderately well	Sandy Clay	28	Nil	<15%	3.21	7.18	0.48	26.49	64.29	0.28	1.48	1-3
45	MRKiB2g1	Moderately well	Sandy Clay	28	Nil	15-35%	3.21	7.18	0.48	26.49	64.29	0.28	1.48	1-3
46	MVDfB2	Well drained	Clay loam	170	Nil	<15%	4.66	6.62	0.52	23.96	84.18	0.2	2.07	1-3
47	MVDfB2g1	Well drained	Clay loam	170	Nil	15-35%	4.66	6.62	0.52	23.96	84.18	0.2	2.07	1-3
48	MVDfD3	Well drained	Clay loam	170	Nil	<15%	4.66	6.62	0.52	23.96	84.18	0.2	2.07	5-10
49	RMNiC3g2	Well drained	Sandy Clay	120	Nil	35-60%	3.2	8.28	0.64	17.35	90.34	0.18	4.65	3-5
50	RMNiD3g2	Well drained	Sandy Clay	120	Nil	35-60%	3.2	8.28	0.64	17.35	90.34	0.18	4.65	5-10
51	SDKhB2	Moderately well	Sandy clay loam	39	Nil	<15%	3.81	6.45	0.56	27.41	69.55	0.16	0.81	1-3
52	SDKhB2g1	Moderately well	Sandy clay loam	39	Nil	15-35%	3.81	6.45	0.56	27.41	69.55	0.16	0.81	1-3
53	SDKiB2g1	Moderately well	Sandy Clay	46	Nil	15-35%	3.85	6.68	0.72	19.92	87.4	0.14	2.61	1-3

Table 1. Contd…..

S. No	Soil Phases	Wetness (w)	Physical condition of Soil (s)					Fertility (f)				Salinity/alkalinity (n)		Erosion (e)
		Drainage	Texture	Depth (cm)	Stoniness	Gravel	CaCO3 %	pH	OC (%)	CEC	BS (%)	EC (dS m-1)	ESP (%)	Slope%
54	SDKiC3g1	Moderately well	Sandy Clay	46	Nil	15-35%	3.85	6.68	0.72	19.92	87.4	0.14	2.61	3-5
55	SGLmB1	Moderately well	Clay	180	Nil	<15%	15.05	8.13	0.45	53.97	92.99	0.21	1.36	1-3
56	SGLmB1g1	Moderately well	Clay	180	Nil	15-35%	15.05	8.13	0.45	53.97	92.99	0.21	1.36	1-3
57	SSKcD3g2	Moderately well	Sandy loam	30	Nil	35-60%	1.25	5.49	0.47	6.18	69.69	0.28	2.56	5-10
58	SSKcE3g2	Moderately well	Sandy loam	30	Nil	35-60%	1.25	5.49	0.47	6.18	69.69	0.28	2.56	10-15
59	SSKhC3g1	Moderately well	Sandy clay loam	30	Nil	15-35%	1.25	5.49	0.47	6.18	69.69	0.28	2.56	3-5
60	UGKmB2	Moderately well	Clay	65	Nil	<15%	3.05	7.13	0.64	29.03	58.28	0.24	1.81	1-3
61	YSJhB2g2	Moderately well	Sandy clay loam	30	Nil	35-60%	0.45	5.55	0.64	14.54	40.22	0.12	1.86	1-3

Results and Discussion

The soil properties of the study area were matched with the soil site suitability criteria for a few important fruit crops grown in north Karnataka. The soil-site suitability for major horticultural crops is presented in Table 2.

Mango

Mango is well adapted to tropical and subtropical climates and thrives well up to 1500 m above mean sea level, but is commercially uneconomical beyond 600 m. In India, it is grown in almost all states and shares about 56 per cent of the total mango production in the world. Andhra Pradesh, Uttar Pradesh, Bihar, Karnataka, Maharashtra, West Bengal and Gujarat together contribute to about 82 per cent of total mango production in India. The mango fruit crop requires a soil depth of more than 200 cm, sandy loam, silt loam, clay loam, loam texture, soils free of salinity and alkalinity and well-drained soils. The most suitable temperature for mango cultivation is 28 °C to 32 °C. The length of the growing period for optimum crop production is more than 180 days. The suitability of soil phases in the Ganjigatti sub-watershed for growing mango indicated that the mapping units were moderately suitable to currently not suitable (N), having moderate, severe and very severe limitations of climate, soil physical properties and sloppiness. Areas of moderately (S2), marginally (S3) and currently not suitable (N) classes for mango were 175 ha (4.04% of TGA), 678 ha (15.66% of TGA) and 3116 ha (72.06% of TGA), respectively (Figure 2). Based on the types of limitations, the soil site suitability class S2 was subdivided into S2cs subclasses, which include MVDfB2 and MVDfB2g1, which are moderately suitable for cultivation due to moderate limitations in annual average temperature and LGP and soil physical factors such as texture, depth and CaCO3 content.

Table 2: Soil-site suitability classification of mapping units for major fruit crops

S. No	Soil Phases	Mango	Guava	Pomegranate	Sapota	Citrus	Grapes
1	AKTmB2R2	S3s	S2cws	S2cws	S2cws	S3cs	S2cws
2	ASRfB2	Ns	Ns	S2c	S2cs	Ns	S2cs
3	ASRfB2g1	Ns	Ns	S2cs	S3s	Ns	S3s
4	ASRmB2	Ns	Ns	S2cs	S2cs	Ns	S2cs
5	ASRmC3	Ns	Ns	S2cse	S2cse	Ns	S2cse
6	BGDhB2g1	Ns	Ns	Ns	Ns	Ns	Ns
7	BGDhC3g2	Ns	Ns	Ns	Ns	Ns	Ns
8	BGHfB2	S3s	S2cws	S2cws	S2cws	S3cs	S2cws
9	BGHfB2g1	S3s	S3s	S2cws	S3s	S3cs	S3s
10	BGHfB2g2	S3s	Ns	S3s	Ns	Ns	Ns
11	BGHfC3	S3s	S2cwse	S2cwse	S2cwse	S3cs	S2cwse
12	BGHfC3g1	S3s	S3s	S2cwse	S3s	S3cs	S3s
13	BGHfD3g2	S3se	Ns	S3se	Ns	Ns	Ns
14	BGHhB2	S3s	S2cws	S2cws	S2cws	S3cs	S2cws
15	BGHhB2g1	S3s	S3s	S2cws	S3s	S3cs	S3s
16	BGHmB1g1St2	S3s	S3s	S2cws	S3s	S3cs	S3s
17	BNKmB1	Ns	Ns	Ns	Ns	Ns	Ns
18	BNKmB1g1	Ns	Ns	Ns	Ns	Ns	Ns
19	BNKmB2g1	Ns	Ns	Ns	Ns	Ns	Ns
20	BNKmC2g2	Ns	Ns	Ns	Ns	Ns	Ns
21	BTPmA1	Ns	S3s	S2cs	S2cs	Ns	S2cs
22	BTPmB2	Ns	S3s	S2cs	S2cs	Ns	S2cs
23	BTPmB2g1	Ns	S3s	S2cs	S3s	Ns	S3s
24	GJGiB2	Ns	S3s	S3s	S3s	S3cs	S3s
25	GJGiB2g1	Ns	S3s	S3s	S3s	S3cs	S3s
26	GJGiC3g1	Ns	S3s	S3s	S3s	S3cs	S3s
27	HNLiC2g1	Ns	S3s	S3s	S3s	S3cs	S3s
28	HNLiC2g2	Ns	S3s	S3s	S3s	S3cs	S3s
29	HRGmB2	Ns	Ns	S2cws	S2cws	Ns	S2cws
30	HRGmB2Ca	Ns	Ns	S2cws	S2cws	Ns	S2cws
31	HRGmC3g1	Ns	Ns	S2cwse	S3s	Ns	S3s
32	KDKhB2g1	Ns	Ns	Ns	Ns	Ns	Ns
33	KDKhC3g2	Ns	Ns	Ns	Ns	Ns	Ns
34	KDKhC3g3	Ns	Ns	Ns	Ns	Ns	Ns
35	KDKiB2	Ns	Ns	Ns	Ns	Ns	Ns
36	KMDhC3g2	Ns	Ns	Ns	Ns	Ns	Ns
37	KMDmB2	Ns	Ns	Ns	Ns	Ns	Ns
38	KMDmB2g1	Ns	Ns	Ns	Ns	Ns	Ns
39	KRKfC2g1	Ns	Ns	Ns	Ns	Ns	Ns
40	KRKmC2g1	Ns	Ns	Ns	Ns	Ns	Ns
41	MLPdB1g1	Ns	Ns	Ns	Ns	Ns	Ns
42	MLPdC2g1	Ns	Ns	Ns	Ns	Ns	Ns
43	MLPdC2g2	Ns	Ns	Ns	Ns	Ns	Ns
44	MRKiB2	Ns	Ns	Ns	Ns	Ns	Ns
45	MRKiB2g1	Ns	Ns	Ns	Ns	Ns	Ns
46	MVDfB2	S2cs	S2cs	S2c	S2cs	S3c	S2cs
47	MVDfB2g1	S2cs	S3s	S2cs	S3s	S3c	S3s
48	MVDfD3	S3e	S3e	S3e	S3e	S3ce	S3e
49	RMNiC3g2	S3s	Ns	S3s	Ns	Ns	Ns
50	RMNiD3g2	S3se	Ns	S3se	Ns	Ns	Ns
51	SDKhB2	Ns	Ns	Ns	Ns	Ns	Ns
52	SDKhB2g1	Ns	Ns	Ns	Ns	Ns	Ns
53	SDKiB2g1	Ns	Ns	Ns	Ns	Ns	Ns
54	SDKiC3g1	Ns	Ns	Ns	Ns	Ns	Ns
55	SGLmB1	Ns	Ns	S2cws	S2cws	Ns	S2cws
56	SGLmB1g1	Ns	Ns	S2cws	S3s	Ns	S3s
57	SSKcD3g2	Ns	Ns	Ns	Ns	Ns	Ns
58	SSKcE3g2	Nse	Nse	Nse	Nse	Nse	Nse
59	SSKhC3g1	Ns	Ns	Ns	Ns	Ns	Ns
60	UGKmB2	Ns	S3s	S3s	S3s	S3cs	S3s
61	YSJhB2g2	Ns	Ns	Ns	Ns	Ns	Ns

Based on the types of limitations, the soil site suitability class S3 was subdivided into subclasses S3e, S3s and S3se. Subclass S3e (MVDfD3) is marginally suitable for cultivation of mango with severe limitations of slope per cent; subclass

S3s includes AKTmB2R2, BGHfB2, BGHfB2g1, BGHfB2g2, BGHfC3, BGHfC3g1, BGHhB2, BGHhB2g1, BGHmB1g1St2 and RMNiC3g2, which are marginally suitable for cultivation with severe limitations of soil physical factors such as depth and CaCO3 content; and subclass S3se (BGHfD3g2 and RMNiD3g2) is marginally suitable for cultivation of mango with severe limitations of both soil physical factors and slope per cent. The area under the S3e, S3s and S3se suitability sub-classes of mango is 17 ha (0.38% of TGA), 609 ha (14.08% of TGA) and 52 ha (1.20% of TGA), respectively. The sub-class Ns includes ASRfB2, ASRfB2g1, ASRmB2, ASRmC3, BGDhB2g1, BGDhC3g2, BNKmB1, BNKmB1g1, BNKmB2g1, BNKmC2g2, BTPmA1, BTPmB2, BTPmB2g1, GJGiB2, GJGiB2g1, GJGiC3g1, HNLiC2g1, HNLiC2g2, HRGmB2, HRGmB2Ca, HRGmC3g1, KDKhB2g1, KDKhC3g2, KDKhC3g3, KDKiB2, KMDhC3g2, KMDmB2, KMDmB2g1, KRKfC2g1, KRKmC2g1, MLPdB1g1, MLPdC2g1, MLPdC2g2, MRKiB2, MRKiB2g1, SDKhB2, SDKhB2g1, SDKiB2g1, SDKiC3g1, SGLmB1, SGLmB1g1, SSKcD3g2, SSKhC3g1, UGKmB2 and YSJhB2g2 mapping units which are currently not suitable for mango cultivation due to very severe limitations in soil physical factors such as depth and CaCO3 content. The sub-class Nse (SSKcE3g2) also currently not suitable for mango cultivation due to very severe limitations in soil physical factors such as depth and slope percent. The area under the Ns and Nse sub-classes of mango was 3110 ha (71.92% of TGA) and 6 ha (0.14% of TGA), respectively. Selvaraj and Naidu (2013) [19] evaluated the soils of Renigunta mandal of Chittoor district Andhra Pradesh for their suitability to mango. Similarly, other fruit crops like citrus, guava, pomegranate and sapota are also facing severe limitation of soil depth.

Guava

Guava is successfully grown in tropical and subtropical climates. It comes up well from sea level to an altitude of 500 M above MSL. In areas with distinct winter seasons, the yield tends to increase with quality. The guava fruit crop requires a soil depth of more than 100 cm, sandy loam, silt loam, clay loam, loam texture, soils free of salinity and alkalinity, and well-drained soils. The most suitable temperature for guava cultivation is 28 °C to 32 °C. The length of the growing period for optimum crop production is more than 150 days. The suitability of soil phases in the Ganjigatti sub-watershed for growing guava indicated that all the mapping units were moderately suitable to currently not suitable (N), having moderate, severe and very severe limitations of climate, soil drainage, soil physical properties and land forms. Areas of moderately (S2), marginally (S3) and currently not suitable (N) classes for guava were 529 ha (12.24% of TGA), 836 ha (19.32% of TGA) and 2603 ha (60.21% of TGA), respectively (Figure 3).

The soil site suitability class S2 is moderately suitable for guava cultivation with moderate limitations in climatic factors, soil drainage, soil physical factors and slope percentage. The S2 class was subdivided into S2cs, S2cws and S2cwse based on the types of limitations present. Subclass S2cs (MVDfB2) is moderately suitable for cultivation with moderate limitations of climatic factors such as mean annual temperature and length of growing period, soil physical factors such as texture, depth, CaCO3 content and gravelines; subclass S2cws (AKTmB2R2, BGHfB2 and BGHhB2) is moderately suitable for cultivation with moderate limitations of climatic factors, soil physical factors such as texture, depth, CaCO3 content and gravelines, and soil drainage; and subclass S2cwse (BGHfC3) is moderately suitable for cultivation of guava with moderate limitations such as length of growing period, soil drainage, soil physical factors and slope%. The area of S2cs, S2cws and S2cwse sub-classes for guava was 157 ha (3.63% of TGA), 320 ha (7.41% of TGA) and 52 ha (1.20% of TGA), respectively.

Based on the types of limitations, the soil site suitability class S3 was subdivided into subclasses S3e and S3s. Subclass S3e (MVDfD3) is marginally suitable for cultivation of guava with severe limitations of slope per cent; and subclass S3s includes BGHfB2g1, BGHfC3g1, BGHhB2g1, BGHmB1g1St2, BTPmA1, BTPmB2, BTPmB2g1, GJGiB2, GJGiB2g1, GJGiC3g1, HNLiC2g1, HNLiC2g2, MVDfB2g1 and UGKmB2, which are marginally suitable for cultivation with severe limitations of soil physical factors such as depth, CaCO3 content and gravelines. The area under the S3e and S3s suitability sub-classes of guava was 17 ha (0.38% of TGA) and 819 ha (18.94% of TGA), respectively. The sub-class Ns includes ASRfB2, ASRfB2g1, ASRmB2, ASRmC3, BGDhB2g1, BGDhC3g2, BGHfB2g2, BGHfD3g2, BNKmB1, BNKmB1g1, BNKmB2g1, BNKmC2g2, HRGmB2, HRGmB2Ca, HRGmC3g1, KDKhB2g1, KDKhC3g2, KDKhC3g3, KDKiB2, KMDhC3g2, KMDmB2, KMDmB2g1, KRKfC2g1, KRKmC2g1, MLPdB1g1, MLPdC2g1, MLPdC2g2, MRKiB2, MRKiB2g1, RMNiC3g2, RMNiD3g2, SDKhB2, SDKhB2g1, SDKiB2g1, SDKiC3g1, SGLmB1, SGLmB1g1, SSKcD3g2, SSKhC3g1 and YSJhB2g2 mapping units which are currently not suitable for guava cultivation due to very severe limitations in soil physical factors such as depth, CaCO3 content and gravelines. The sub- class Nse (SSKcE3g2) is also currently not suitable for guava cultivation due to very severe limitations in soil physical factors such as depth, gravelines and slope percent, respectively. The area under the Ns and Nse sub-classes of guava was 2597 ha (60.07% of TGA) and 6 ha (0.14% of TGA), respectively. Similar results were reported by Anilkumar *et al.* (2019) [3] in the Haradanahalli micro watershed and D Souza and Patil (2021) [5] in the Kanamadi south sub- watershed.

Pomegranate

Pomegranate adapts to a wide range of climatic conditions. It grows well in plains as well as on hills up to an elevation of 2000 M above MSL. It is a hardy plant that can withstand drought. The pomegranate fruit crop requires a soil depth of more than 100 cm, sandy loam, silt loam, clay loam, loam texture, soils free of salinity and alkalinity, and well-drained soils. The most suitable temperature for pomegranate cultivation is 30 °C to 34 °C. The length of the growing period for optimum crop production is more than 150 days. The suitability of soil phases in the Ganjigatti sub-watershed for growing pomegranate indicated that all the mapping units were moderately suitable to currently not suitable (N), having moderate, severe and very severe limitations of climate, soil drainage, soil physical properties and land forms. Areas of moderately (S2), marginally (S3) and currently not suitable (N) classes for pomegranate were 1927 ha (44.58% of TGA), 465 ha (10.75% of TGA) and 1575 ha (36.43% of TGA), respectively (Figure 4).

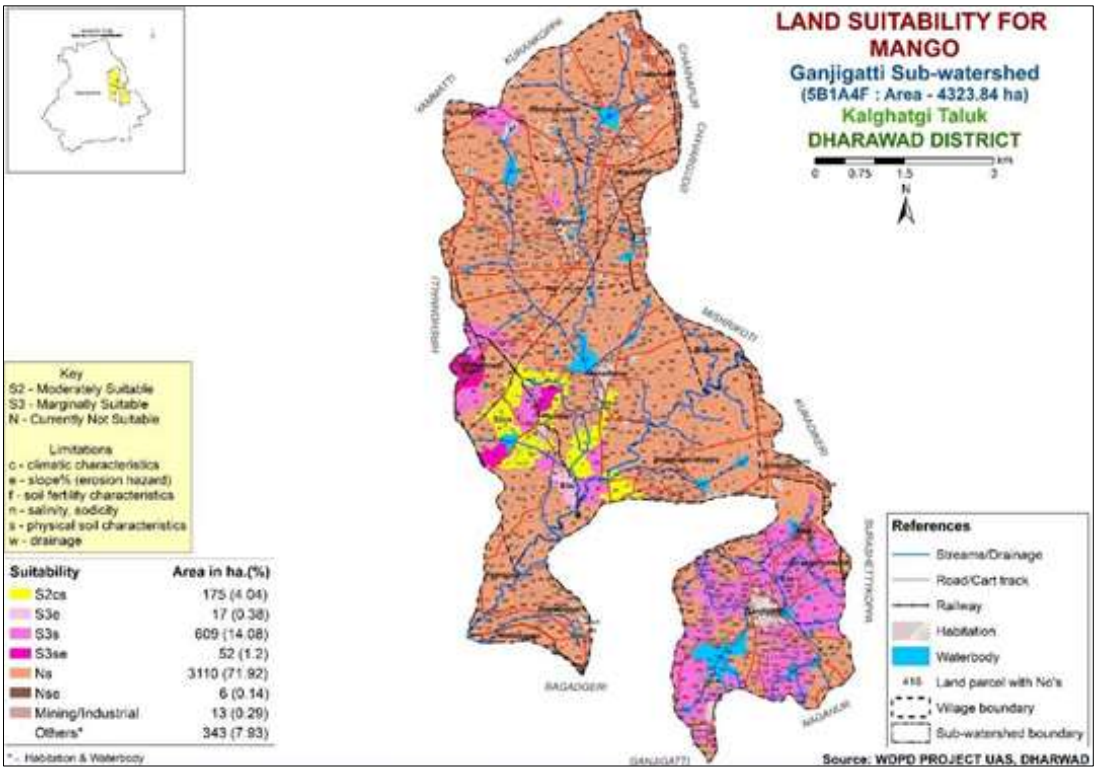

Fig 2: Soil-site suitability map for mango crop in Ganjigatti sub-watershed

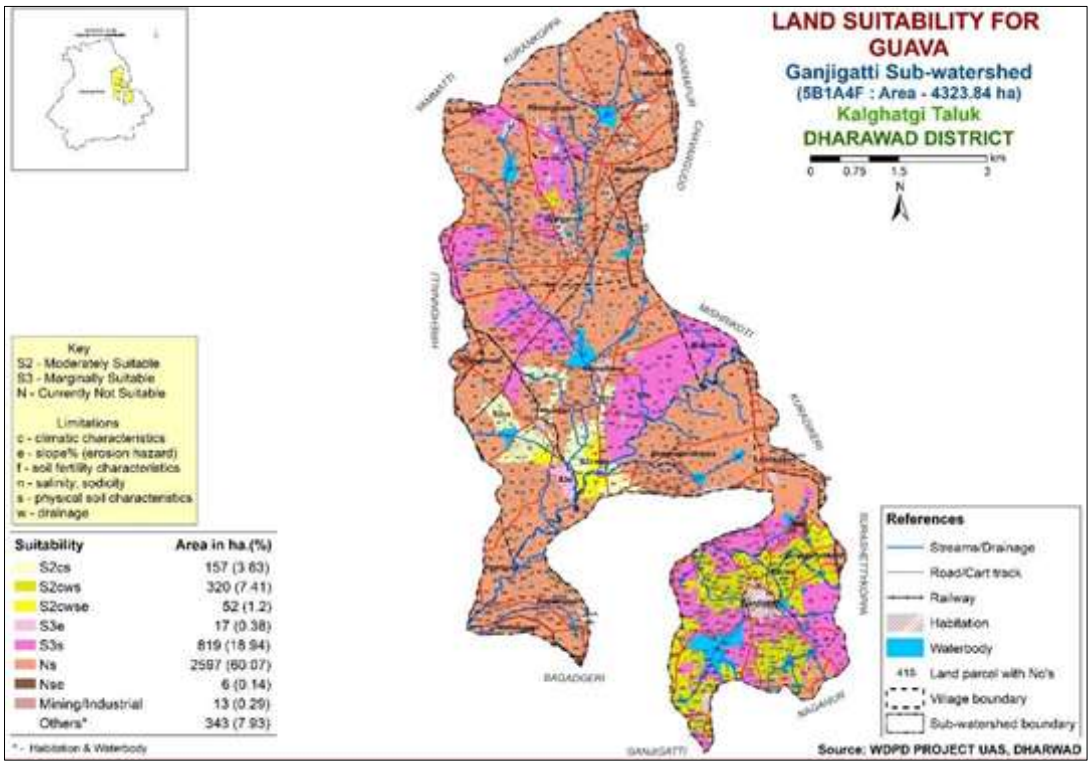

Fig 3: Soil-site suitability map for guava crop in Ganjigatti sub-watershed

The soil site suitability class S2 is moderately suitable for pomegranate cultivation with moderate limitations in climatic factors, soil drainage, soil physical factors and slope percentage.

The S2 class was subdivided into S2c, S2cs, S2cse, S2cws and S2cwse based on the types of limitations present. Subclass S2c (ASRfB2 and MVDfB2) is moderately suitable for cultivation with moderate limitations of climatic factors such as mean annual temperature and length of growing period; Subclass S2cs includes mapping units namely ASRfB2g1, ASRmB2, BTPmA1, BTPmB2, BTPmB2g1 and MVDfB2g1 which are moderately suitable for cultivation due to moderate limitations of climatic factors such as mean annual temperature and length of growing period, and soil physical factors such as texture, depth, and gravelines; Subclass S2cse (ASRmC3) is moderately suitable for cultivation with moderate limitations of climatic factors such as mean annual temperature and length of growing period,

soil physical factors such as texture, depth and gravelines, and soil slope per cent; the mappings units namely AKTmB2R2, BGHfB2, BGHfB2g1, BGHhB2, BGHhB2g1, BGHmB1g1St2, HRGmB2, HRGmB2Ca, SGLmB1 and SGLmB1g1
classified under subclass S2cws, which is moderately suitable for cultivation due to moderate limitations of climatic factors, soil physical factors such as texture, depth and gravelines, and soil drainage; and subclass S2cwse (BGHfC3, BGHfC3g1 and HRGmC3g1) is moderately suitable for cultivation of pomegranate due to moderate limitations such as length of growing period, soil drainage, soil physical factors and slope%. The area of S2c, S2cs, S2cse, S2cws and S2cwse sub- classes for pomegranate was 200 ha (4.63% of TGA), 620 ha (14.34% of TGA), 9 ha (0.21% of TGA), 1021 ha (23.61% of TGA) and 77 ha (1.79% of TGA), respectively.
Based on the types of limitations, the soil site suitability class S3 was subdivided into subclasses S3e, S3s and S3se. Subclass S3e (MVDfD3) is marginally suitable for cultivation of pomegranate with severe limitations of slope per cent; subclass S3s includes the mapping units namely BGHfB2g2, GJGiB2, GJGiB2g1, GJGiC3g1, HNLiC2g1, HNLiC2g2, RMNiC3g2 and UGKmB2, which are marginally suitable for cultivation due to severe limitations of soil physical factors such as depth and graveliness; and subclass S3se (BGHfD3g2 and RMNiD3g2) is marginally suitable for cultivation of pomegranate with severe limitations of both soil physical factors and slope per cent. The area under the S3e, S3s and S3se suitability sub-classes of pomegranate was 17 ha (0.38% of TGA), 396 ha (9.17% of TGA) and 52 ha (1.20% of TGA), respectively. The sub-class Ns includes BGDhB2g1, BGDhC3g2, BNKmB1, BNKmB1g1, BNKmB2g1, BNKmC2g2, KDKhB2g1, KDKhC3g2, KDKhC3g3, KDKiB2, KMDhC3g2, KMDmB2, KMDmB2g1, KRKfC2g1, KRKmC2g1, MLPdB1g1, MLPdC2g1, MLPdC2g2, MRKiB2, MRKiB2g1, SDKhB2, SDKhB2g1, SDKiB2g1, SDKiC3g1, SSKcD3g2, SSKhC3g1
and YSJhB2g2, mapping units that are currently not suitable for guava cultivation due to very severe limitations in soil physical factors such as depth, CaCO3 content and gravelines. The sub- class Nse (SSKcE3g2) is also currently not suitable for guava cultivation due to very severe limitations in soil physical factors such as depth, gravelines and slope percent, respectively. The area under the Ns and Nse sub-classes of pomegranate was 1569 ha (36.29% of TGA) and 6 ha (0.14% of TGA), respectively. Similar results were obtained by Manjunata *et al.* (2017) [14] and D Souza and Patil (2021) [5].

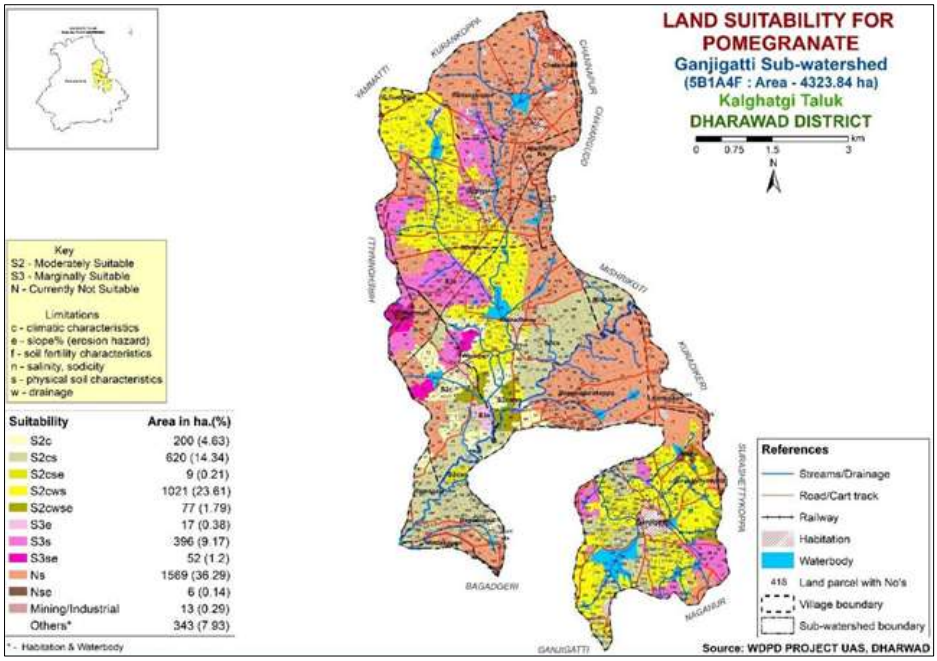

Fig 4: Soil-site suitability map for pomegranate crop in Ganjigatti sub-watershed

that the mapping units were moderately suitable to currently not suitable (N), having moderate, severe and very severe limitations of climate, soil drainage, soil physical properties and land forms. Areas of moderately (S2), marginally (S3) and currently not suitable (N) classes for sapota were 1501 ha (34.71% of TGA), 753 ha (17.39% of TGA) and 1715 ha (39.66% of TGA), respectively (Figure 5).
The soil site suitability class S2 is moderately suitable for sapota cultivation with moderate limitations in climatic factors, soil drainage, soil physical factors and slope percentage. The S2 class was subdivided into S2cs, S2cse, S2cws and S2cwse based on the types of limitations present. Subclass S2cs includes soil mapping units namely ASRfB2, ASRmB2, BTPmA1, BTPmB2 and MVDfB2, which are moderately suitable for cultivation due to moderate limitations of climatic factors such as mean annual temperature and length of growing period, and soil physical factors such as texture, depth, and gravelines; Subclass S2cse (ASRmC3) is moderately suitable for cultivation with moderate limitations of climatic factors such as mean annual temperature and length of growing period, soil physical factors such as texture, depth and gravelines, and soil slope per cent; the mapping units such as AKTmB2R2, BGHfB2, BGHhB2, HRGmB2, HRGmB2Ca and SGLmB1 classified under subclass S2cws, which is moderately suitable for cultivation with moderate limitations of climatic factors, soil physical factors such as texture, depth and gravelines, and soil drainage; and subclass S2cwse (BGHfC3) is moderately

suitable for cultivation of sapota with moderate limitations such as length of growing period, soil drainage, soil physical factors and slope%. The area of S2cs, S2cse, S2cws and S2cwse sub-classes for sapota was 743 ha (17.18% of TGA), 9 ha (0.21% of TGA), 697 ha (16.12% of TGA) and 52 ha (1.20% of TGA), respectively.

Based on the types of limitations, the soil site suitability class S3 was subdivided into subclasses S3e and S3s. Subclass S3e is marginally suitable for cultivation of sapota with severe limitations of slope per cent; and subclass S3s includes mapping units namely ASRfB2g1, BGHfB2g1, BGHfC3g1, BGHhB2g1, BGHmB1g1St2, BTPmB2g1, GJGiB2, GJGiB2g1, GJGiC3g1, HNLiC2g1, HNLiC2g2, HRGmC3g1, MVDfB2g1, SGLmB1g1 and UGKmB2,

which are marginally suitable for cultivation with severe limitations of soil physical factors such as depth and gravelines. The area under the S3e and S3s suitability sub-classes of sapota was 17 ha (0.38% of TGA) and 736 ha (17.01% of TGA), respectively. The sub-class Ns includes BGDhB2g1, BGDhC3g2, BGHfB2g2, BGHfD3g2, BNKmB1, BNKmB1g1, BNKmB2g1, BNKmC2g2, KDKhB2g1, KDKhC3g2, KDKhC3g3, KDKiB2, KMDhC3g2, KMDmB2, KMDmB2g1, KRKfC2g1, KRKmC2g1, MLPdB1g1, MLPdC2g1, MLPdC2g2, MRKiB2, MRKiB2g1, RMNiC3g2, RMNiD3g2, SDKhB2, SDKhB2g1, SDKiB2g1, SDKiC3g1,

SSKcD3g2, SSKhC3g1 and YSJhB2g2 mapping units which are currently not suitable for sapota cultivation due to very severe limitations in soil physical factors such as depth and gravelines. The sub-class Nse (SSKcE3g2) is also currently not suitable for sapota cultivation due to very severe limitations in soil physical factors such as depth, gravelines and slope percent, respectively. The area under the Ns and Nse sub-classes of sapota was 1709 ha (39.52% of TGA) and 6 ha (0.14% of TGA), respectively. Similar results regarding the limitation of rooting conditions and texture were reported by Madhusudan (2019) [12] and D Souza and Patil (2021) [5].

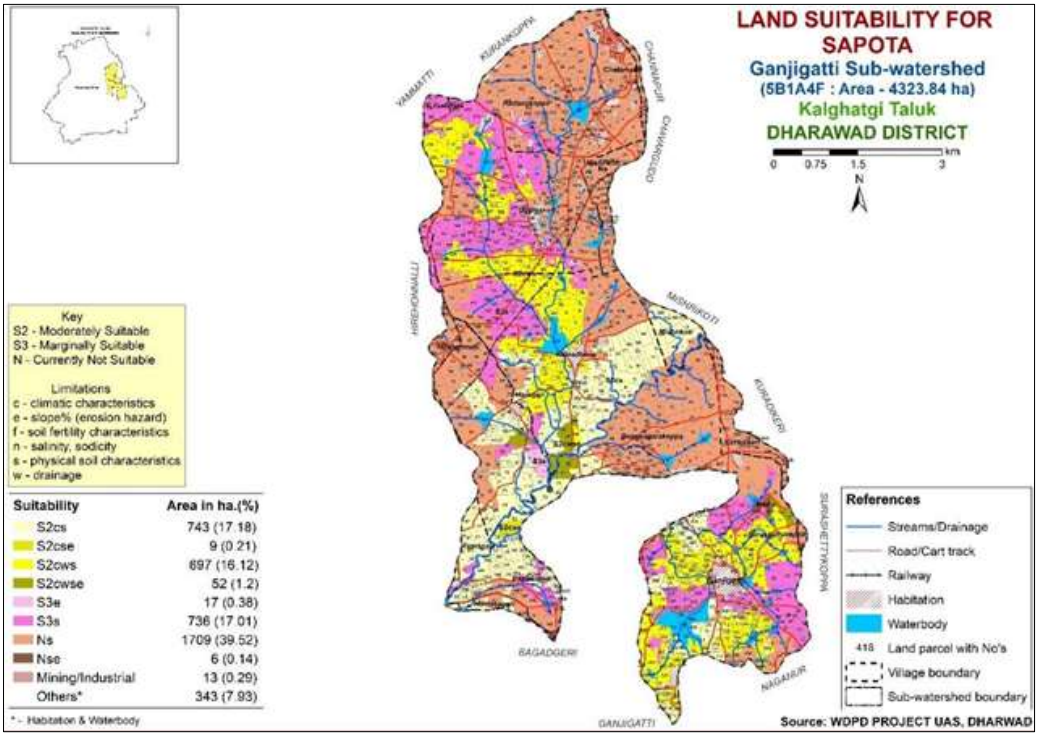

Fig 5: Soil-site suitability map for sapota crop in Ganjigatti sub-watershed

Citrus

The citrus fruit crop requires a soil depth of more than 150 cm, sandy loam, silt loam, clay loam, loam texture, soils free of salinity and alkalinity, and well-drained soils. The most suitable temperature for mango cultivation is 28 °C to 30 °C. The length of the growing period for optimum crop production is 240–265 days. The suitability of soil phases in the Ganjigatti sub-watershed for growing citrus indicated that the mapping units were marginally suitable (S3) and currently not suitable (N), having moderate, severe and very severe limitations of climate, soil drainage, soil physical properties and land forms. Areas of marginally suitable (S3) and currently not suitable

(N) classes for citrus were 1022 ha (23.62% of TGA) and 2946 ha (68.14% of TGA), respectively (Figure 6).

The soil site suitability class S3 is marginally suitable for citrus cultivation with severe limitations in climatic factors, soil physical factors and slope percentage. The S3 class was subdivided into S3c, S3ce and S3cs based on the types of limitations present. Subclass S3c (MVDfB2 and MVDfB2g1) is marginally suitable for cultivation with severe limitations of climatic factors such as length of growing period; Subclass S3ce (MVDfD3) is marginally suitable for cultivation with severe limitations of climatic factors such as length of growing period and soil slope per cent; subclass S3cs includes soil mapping units namely AKTmB2R2, BGHfB2, BGHfB2g1, BGHfC3, BGHfC3g1, BGHhB2, BGHhB2g1, BGHmB1g1St2, GJGiB2, GJGiB2g1,

GJGiC3g1, HNLiC2g1, HNLiC2g2 and UGKmB2, which are marginally suitable for cultivation due to severe limitations of climatic factors and soil physical factors such as depth, CaCO3 content and gravelines. The area of S3c, S3ce and S3cs sub-classes for citrus was 175 ha (4.04% of TGA), 17 ha (0.38% of TGA) and 830 ha (19.20% of TGA), respectively.

The sub-class Ns includes ASRfB2, ASRfB2g1, ASRmB2, ASRmC3, BGDhB2g1, BGDhC3g2, BGHfB2g2, BGHfD3g2, BNKmB1, BNKmB1g1, BNKmB2g1, BNKmC2g2, BTPmA1, BTPmB2, BTPmB2g1, HRGmB2, HRGmB2Ca, HRGmC3g1, KDKhB2g1, KDKhC3g2, KDKhC3g3, KDKiB2, KMDhC3g2, KMDmB2, KMDmB2g1, KRKfC2g1, KRKmC2g1, MLPdB1g1, MLPdC2g1, MLPdC2g2, MRKiB2, MRKiB2g1, RMNiC3g2, RMNiD3g2, SDKhB2, SDKhB2g1, SDKiB2g1, SDKiC3g1, SGLmB1, SGLmB1g1, SSKcD3g2,
SSKhC3g1 and YSJhB2g2 mapping units, which are currently not suitable for citrus cultivation due to very severe limitations in soil physical factors such as depth, CaCO3 content and gravelines. The sub-class Nse (SSKcE3g2) is also currently not suitable for citrus cultivation due to very severe limitations in soil physical factors such as depth, CaCO3 content, gravelines and slope percent, respectively. The area under the Ns and Nse sub-classes of citrus was 2940 ha (68.00% of TGA) and 6 ha (0.14% of TGA), respectively. The results are in accordance with Rajesh *et al.* (2019), who reported that Adavibhavi microwatershed was found to be currently not suitable (N1).
due to severe limitations of rooting condition slope, texture and gravel, and Mahesh *et al.* (2019), who reported that Bharatnur-3 micro-watershed was moderately suitable (S2lt) with limitations to texture and topography and not suitable with limitations to rooting depth and topography.

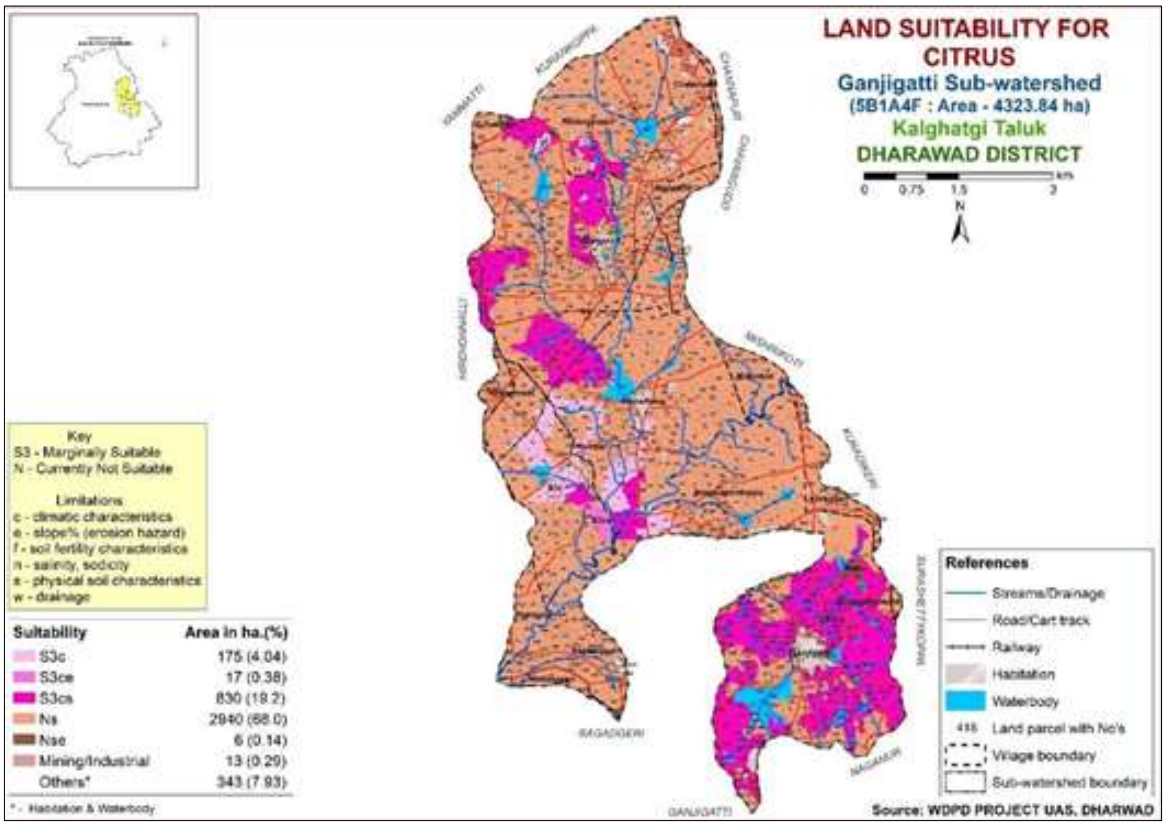

Fig 6: Soil-site suitability map for citrus crop in Ganjigatti sub-watershed

Grapes

Areas receiving greater than 100 cm annual rainfall are most suitable for grapes cultivation. Yields on deep, fertile soils are generally higher. Too sandy or too heavy clay soils, with high concentration of salts of alkali metals or other toxic substances may not be favourable for grapes. The grape crop requires a soil depth of 100 to 150 cm, sandy loam, silt loam, clay loam, loam texture, soils free of salinity and alkalinity, and well-drained soils. The most suitable temperature for guava cultivation is 25 °C to 30 °C. The mean relative humidity for optimum crop production is 50–60%. The suitability of soil phases in the Ganjigatti sub-watershed for growing grapes indicated that the mapping units were moderately suitable to currently not suitable (N), having moderate, severe and very severe limitations of climate, soil drainage, soil physical properties and land forms. Areas of moderately (S2), marginally (S3) and currently not suitable (N) classes for grapes were 1501 ha (34.71% of TGA), 753 ha (17.39% of TGA) and 1715 ha (39.66% of TGA), respectively (Figure 7).
The soil site suitability class S2 is moderately suitable for grape cultivation with moderate limitations in climatic factors, soil drainage, soil physical factors and slope percentage. The S2 class was subdivided into S2cs, S2cse, S2cws and S2cwse based on the types of limitations present. Subclass S2cs includes mapping units namely ASRfB2, ASRmB2, BTPmA1, BTPmB2 and MVDfB2, which are moderately suitable for cultivation with moderate limitations of climatic factors such as mean annual temperature and length of growing period, and soil physical factors such as texture, depth, and gravelines; Subclass S2cse (ASRmC3) is moderately suitable for cultivation with moderate limitations of climatic factors such as mean annual temperature and length of growing period, soil physical factors such as texture, depth and gravelines, and soil slope per cent; the mapping units AKTmB2R2, BGHfB2, BGHhB2, HRGmB2, HRGmB2Ca and SGLmB1 classified under subclass S2cws, which is moderately suitable for cultivation due to moderate

limitations of climatic factors, soil physical factors such as texture, depth and gravelines, and soil drainage; and subclass S2cwse (BGHfC3) is moderately suitable for cultivation of grapes with moderate limitations such as length of growing period, soil drainage, soil physical factors and slope%. The area of S2cs, S2cse, S2cws and S2cwse sub-classes for grapes was 743 ha (17.18% of TGA), 9 ha (0.21% of TGA), 697 ha (16.12% of TGA) and 52 ha (1.20% of TGA), respectively.

Based on the types of limitations, the soil site suitability class S3 was subdivided into subclasses S3e and S3s. Subclass S3e (MVDfD3) is marginally suitable for cultivation of grapes with severe limitations of slope per cent; and subclass S3s includes ASRfB2g1, BGHfB2g1, BGHfC3g1, BGHhB2g1, BGHmB1g1St2, BTPmB2g1, GJGiB2, GJGiB2g1, GJGiC3g1, HNLiC2g1, HNLiC2g2, HRGmC3g1, MVDfB2g1, SGLmB1g1 and UGKmB2, which are marginally suitable for cultivation due to severe limitations of soil physical factors such as depth and gravelines. The area under the S3e and S3s suitability sub-classes of grapes was 17 (0.38% of TGA) and 736 (17.01% of TGA), respectively. The sub-class Ns includes BGDhB2g1, BGDhC3g2, BGHfB2g2, BGHfD3g2, BNKmB1, BNKmB1g1, BNKmB2g1, BNKmC2g2, KDKhB2g1, KDKhC3g2, KDKhC3g3, KDKiB2, KMDhC3g2, KMDmB2, KMDmB2g1, KRKfC2g1, KRKmC2g1, MLPdB1g1, MLPdC2g1, MLPdC2g2, MRKiB2, MRKiB2g1, RMNiC3g2, RMNiD3g2, SDKhB2, SDKhB2g1, SDKiB2g1, SDKiC3g1, SSKcD3g2, SSKhC3g1 and YSJhB2g2 mapping units, which are currently not suitable for grape cultivation due to very severe limitations in soil physical factors such as depth and gravelines. The sub-class Nse (SSKcE3g2) is also currently not suitable for grape cultivation due to very severe limitations in soil physical factors such as depth, gravelines and slope percent. The area under the Ns and Nse sub-classes of grapes was 1709 ha (39.52% of TGA) and 6 ha (0.14% of TGA), respectively. Similar results of marginally suitable to not suitable for grapes in the Kanaginahala sub-watershed due to severe limitations of texture and pH were reported by Madhusadan (2019) [12] and Manjunata *et al.* (2017) [14] in the Chikamageri microwatershed.

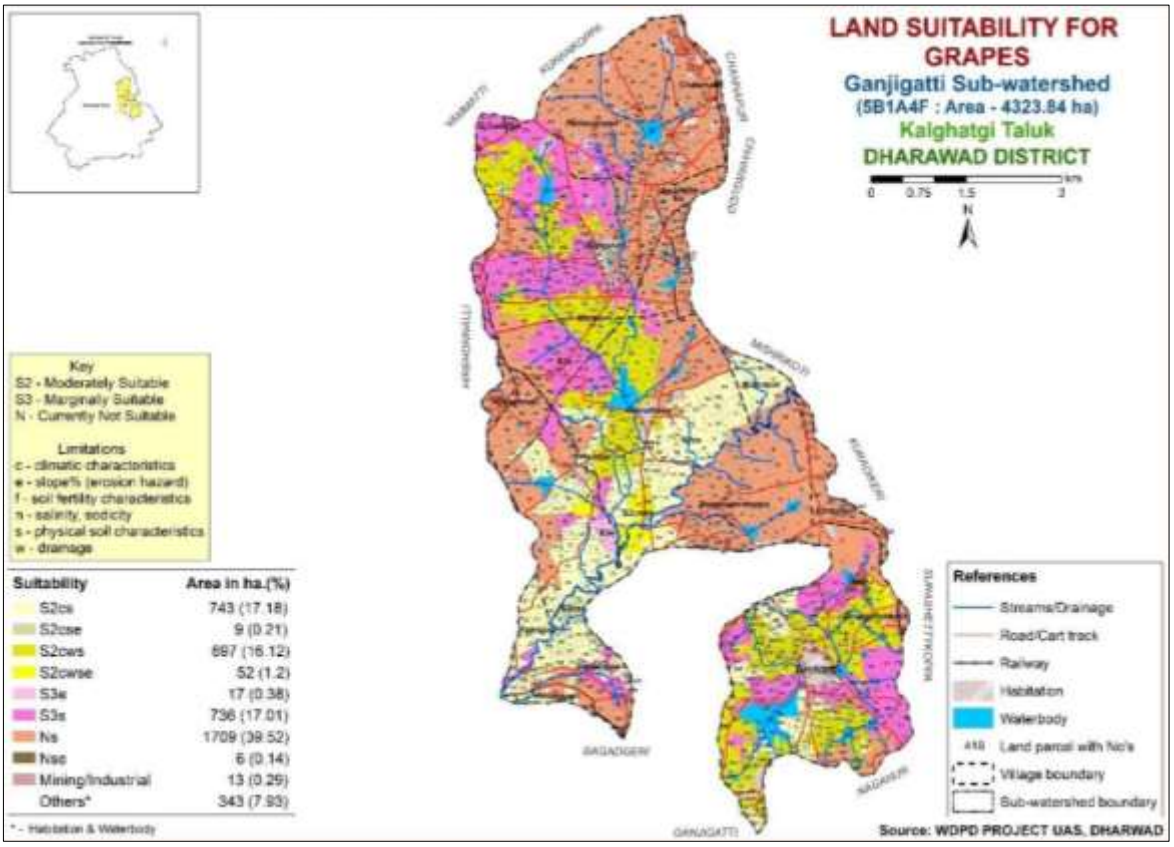

Fig 7: Soil-site suitability map for grapes crop in Ganjigatti sub-watershed

Conclusion

It is concluded that the soils of the Ganjigatti sub-watershed showed different degrees of suitability for growing mango, guava, pomegranate, sapota, citrus and grapes. The soil series BGD, BNK, KDK, KMD, KRL, MLP, MRK, SDK, SSK and YSJ are currently not suitable for the production of mango, guava, pomegranate, sapota, citrus and grapes due to very severe limitations of soil depth and slop per centage. Whereas the AKT, BGH and MVD series are moderately to marginally suitable for cultivation of these six fruit crops. The main limitations in all the soil series.

found to be shallow soil depth, slope, texture, CaCO3 content and climatic factors. However, the degree of these limitations in all these soil series varies from slight to very severe. Further, integrated use of organic manures and inorganic fertilizers not only paves the way to achieve sustainable yields of crops but also sustains the soil health for future generations without undergoing deterioration and also helps in doubling the farmer's income.

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