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Soil Suitability of Some Major Fruit Crops for Sustainable Production in the IGP Region of India-A Case Study

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ABSTRACT: Horticultural crops, particularly the fruit crops are important for ensuring nutritional security as well as livelihood security. However, the fruit crops occupy less area compare to cereals and other agricultural crops and the declining landholdings size due to fast population growth and urbanization further jeopardize the area under fruit crops. Thus, for ensuring effective and efficient utilization of the lands possibilities of alternate land use options such as fruits crop cultivation need to be explored. In this context, land evaluation in terms of soil suitability assessment is an important tool for identifying suitable areas for fruit crop production. But lack of information on soil-site suitability poses great challenge to the policy planners and other development agencies. Thus, the study was carried out in the *Chhata tehsil* of upper Indo-Gangetic Plain (IGP) region of IGP of India with the aim of mapping the suitable areas for various agro-horticultural crops including the fruit crops. Results reveal that maximum area (60.9 per cent) evaluated to be highly suitable (S1) for papaya followed by 22.2% for mango cultivation. Maximum area *i.e.*, 83.1 and 74.4% evaluated to be under moderately suitable class (S2) for citrus and ber crops while, for mango (59.3%) and guava (54.3%) cultivation maximum area found to be under marginally suitable class (S3). Therefore, the present study will be of immense use to the policy planners and other developmental agencies for ensuring effective implementation of various programmes/schemes oriented towards fruit crops cultivation.

Keywords: IGP region; fruit crops; soil suitability; sustainable production

INTRODUCTION

Horticultural crops, particularly the fruit crops are important for ensuring nutritional security and employment opportunity and thus, vital for livelihood security. Horticulture production system (fruit crop based) is economically viable and more adoptable (Chundawat, 1993; Chadha, 2002). Integration of annual field crops with fruit crops results in high yield and income (Osman, 2003). Now a day's horticulture system is becoming more important to arrest land degradation and improving the income, and thus holds great promise for diversification of marginal land. With the advancement of science and technology driven intervention, it is quite feasible to improve the quality of land and soils. However, rapid population growth acts as a limiting factor to the availability of arable lands around the world. Consequent upon it, the need was felt for effective and efficient utilization of the croplands. In this context, adoption of suitable crops could open new avenues to nutritional security besides, scope for extension of new areas for such crops (More *et al.,* 2012).

According to FAO (1976), suitability is a statement of the adaptability of a given area for a specific kind of land use. The evaluation process, therefore, provides information on the major constraints and opportunities for the use of land for particular use types which will guide decision-makers on how resources are optimally utilized. Agricultural land suitability assessment is the process of land performance assessment when the land is used for alternative kinds of agriculture (Prakash, 2003; Mu, 2006; He *et al.,* 2011; Darwish and Kawy, 2014; Diallo *et al.,* 2016; Ahmed, 2016). The main purpose of agricultural land suitability evaluation is to predict the potential and limitation of the land for crop production (Pan and Pan, 2012; AbdelRahman *et al.*, 2016). Besides, to achieve the goal of sustainable agriculture it is also important to emphasize on proper land categorization and its utilization based upon their different uses (FAO, 1993). Better delineation of soil and land suitability for optimum soil and land management requires information on soil and related properties which can be obtained from proper soil survey and soil classification. Since, the performance of any crop depends to a great extent on the soil-site characteristics *i.e.,* soil properties such as depth, drainage, texture, pH, electrical conductivity (EC) etc., as conditioned by climate and topography (Bargali *et al.,* 1993). As the soil-site characterization for predicting the crop performance of an area is important constituents of land evaluation process (Arora *et al.,* 2011). Khadse and Gaikwad (1995) suggested evaluation of yield influencing factors and application of such results on similar soils occurring elsewhere in similar agro-climate sub-region through scientific management practices.

However, the information on soil-site suitability evaluation for Indo-Gangetic Plain (IGP) region is either not available or very scanty information is available for policy planners. Therefore, the present study aims to provide the information about alternate land use options such as suitability of fruit crops for the IGP in readily recognizable form *i.e.,* depiction of suitable and non-suitable areas through mapping with the help of GIS (Geographical Information System) technology.

MATERIALS AND METHODS

The study area *Chhata tehsil* of Mathura district, Uttar Pradesh comes under upper IGP of the IGP region of India. It is located between 27^o 33′ to 27^o 56′N latitudes and 77^o 17′ to 77 ^{o} 42′E longitudes. The area is surrounded by Faridabad district (Haryana) in the north, river Yamuna in the East, Mathura tehsil in the south and district Bharatpur (Rajasthan) in the west. *Chhata tehsil* occupy 1063.5 km^2 area which covered under Survey of India toposheets (1:50,000 scale)) No. 54E/5, 54E/6, 54E/9 and 54E/10. Mean elevation is 185 m above mean sea level (MSL) however, some hillocks has higher elevations ranging from 220-240 m above MSL. The climate of the area is semi arid and characterized by a hot dry summer and very cold winter. The mean minimum, maximum and annual temperature is 14.37, 37.15 and 25.73°C, respectively while average annual rainfall is 655.5 mm, most of which received during rainy season (June-September).

Soil suitability evaluation for fruit crops were carried out following matching crop requirement criteria scheme proposed by Sys (1985) and modified by Naidu *et al.* (2006). Soil suitability groupings were assigned at various levels *viz.,* order *i.e.,* S (suitable) and N (not suitable), reflecting the kind of suitability as per the FAO framework for land evaluation (1976). Order S, further grouped into highly suitable (S1), moderately suitable (S2) and marginally suitable (S3) classes while, order N into presently not suitable (N1) and permanently not suitable (N2) classes, reflecting the degree of suitability within the order. The appraisal of the classes within the order is done according to evaluation of land limitation. The limitations include climate (c), wetness (w), erosion (e) and physical soil limitation (s). Soil suitability maps were generated under Geographical Information System (GIS) environment using GIS software.

RESULTS AND DISCUSSION

A. Soils of the study area

Twenty eight soil units (consists of soil series associations) identified in *Chhata tehsil* and these associations were mapped into 9 soil series (reflects the characteristics, classification, distribution, and behavior and use potentials of the soils in the area) (Fig. 1). The detailed features along with the legend descriptions of soil series are given in Table 1. The physico-chemical properties of the soils considered in soil suitability evaluation have been presented in Table 2. The soils textural variation ranged from loamy sand to clay and gravelly sandy loam. The wide textural variation might be due to variation in parent material, topography and age of the soils (Kumar and Naidu, 2012). The soils pH ranged from 6.5-7.5 to as high as >9.0 in some of the soil series. Differences in soil pH may be attributed to varying parent material, presence of calcium carbonate and exchangeable sodium (Devi and Anil Kumar, 2010). Majority of the soils (76.3%) recorded normal EC (<0.8 dSm^{-1}) whereas, slightly saline to saline area together constitutes to 22.8%. High EC values may be ascribed to the presence of more soluble salts due to leaching, and their transportation by water and deposition in relatively lowlands (Ram *et al.,* 2010). Organic carbon (OC) content in majority of the soils observed to be low whereas, CEC, BS and AWC ranged from low to medium in the study area. Low organic carbon status may be ascribed to poor soil fertility management and depositional activities of alluvium (Srinivasarao, 2011). High CEC is directly related to type and clay content and organic carbon content of the soils whereas, low CEC and BS may be due to good drainage conditions.

B. Soil-site suitability for different fruit crops

Soil-site Suitability for Mango. Mango (*Mangifera indica*) popularly known as king of fruits is well adapted to tropical and subtropical climate. It can be grown on wide range of soils *i.e.,* from alluvial to laterite, having slightly acidic soils reaction (pH 5.5 to 7.0) and can be grown upto pH 8.7 under proper nutrient management. It requires deep and well drained soil condition for its optimum growth and yield. The crop is sensitive to saline/sodic conditions, waterlogging, and free high $CaCO_3$ content and high pH in sub-surface soil layers. The areas experiencing frequent rains or high relative humidity during flowering period are not conducive for good fruit setting. The most favourable temperature for its growth is around 25°C. Soils were evaluated for their suitability to mango cultivation based on the soil and site characteristics *i.e.,* crop requirement and agro-climate of the area.

Table 1: Characteristics and Classification of soils of the study area.

Symbol on map	Soil Series	Soil characteristics	USDA classification	Area in ha (%)
	Simri	Soils are very deep, moderately to imperfectly drained, loam to clay loam, calcareous soils with lime kankar below 50 cm sodic in nature.	*Typic Halaquepts*	9231.6 (8.7%)
	Garhsauli	Soils are very deep, moderately well drained, loam to clay loam, calcareous soils with few lime nodules below 75 cm.	*Typic Haplustepts*	2292.0 (2.2%)
	Tarauli	Very deep, well drained, sandy loam, calcareous soils.	*Typic Haplustepts*	11495.8 (10.8%)
	Neri	Very deep soils, well drained/moderately well drained, sandy loam loam, calcareous soils with lime kankar below 75 cm (hard pan).	*Typic Haplustepts*	9255.6 (8.7%)
	Chhatikara	Very deep soils, well drained, sandy loam soils.	*Typic Haplustepts*	12733.6 (12.0%)
	Chhata	Soils are very deep, well drained, sandy loam with few Fe-Mn nodules below 70 cm.	*Typic Haplustepts*	23629.0 (22.2%)
	Bechhawan Bihari	Very deep soils subject to annual flood, somewhat excessively drained, loamy sand over sandy.	*Typic Ustipsamments*	5251.4 (4.9%)
	Ladpur	Soils are very deep, moderately well drained, sandy loam to loam soils with few Fe-Mn nodules below 50 cm depth.	*Typic Haplustepts*	31235.0 (29.4%)
	Barsana	Soils are shallow, excessively drained, gravelly sandy loam soils on 15-30% slopes.	*Lithic Ustorthents*	261.0 (0.3%)
	Misc.	Habitations, Water bodies/River, Roads, Rock out crops		919.5 (0.9%)
	Total			106304.5

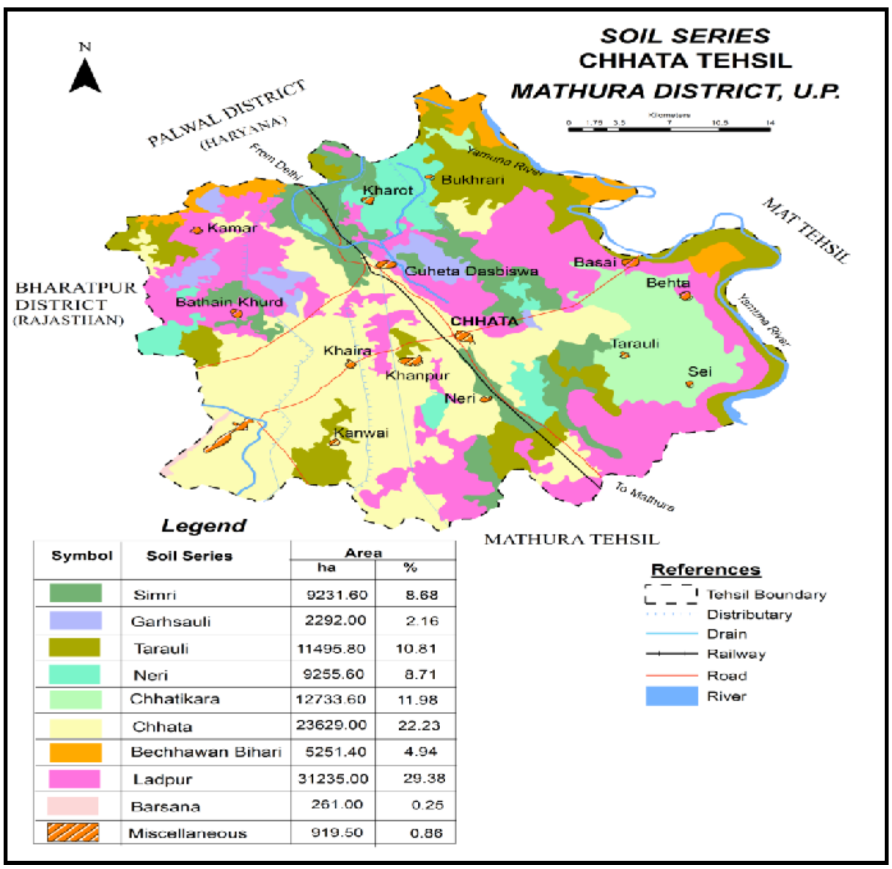

Fig. 1. Soil series map.

Table 2 : Dominant soil physico-chemical properties of the soils of study area.

Soil physico-chemical properties (only those classes considered wherein soil qualified)					
A. Depth class	Very deep	Deep	Mod. Deep	Shallow	Very shallow
Area in ha (%)	Majority of the study area comes under very deep soil depth class except Barsana series				
B. Textural class	Clay loam	Loam	Sandy loam	Loamy sand	Gravelly sandy loam
Area in ha (%)	9231.6 (8.7%)	33527.0 (31.5%)	57114.0 (53.7%)	5251.4 (4.9%)	261.0 (0.3%)
C. Slope	Nearly level to very gently sloping (0-1% slope)	Gently sloping (1-3% slope)	Moderately steeply sloping (15-30% slope)		
Area in ha (%)	99872.6 (93.9%)	5251.4 (4.9%)	261.0 (0.3%)		
D. Erosion	Slight to nil	Slight	Moderate		
Area in ha (%)	99872.6 (93.9%)	5251.4 (4.9%)	261.0 (0.3%)		
E. Drainage	Well drained	Moderately well drained	Excessively drained	Somewhat excessively drained	Moderately to imperfectly drained
Area in ha (%)	57114.0±9255.6 (53.7±8.7%)	33527.0±9255.6 (31.6±8.7%)	261.0 (0.3%)	5251.4 (4.9%)	9231.6 (8.7%)
F. Soil reaction (pH)	Neutral (6.5-7.5)	Moderately alkaline (8.0-8.5)	Strongly alkaline (8.5-9.0)	Very strongly alkaline (>9.0)	
Area in ha (%)	31496.0 (29.6%)	62365.4 (58.7%)	2292.0 (2.2%)	9231.6 (8.7%)	
G. Soil Salinity (EC)	Normal (<0.8 dSm^{-1})	Slightly saline (<0.8- 1.6 dSm^{-1})	Saline (>1.6 dSm^{-1})		
Area in ha (%)	81127.8 (76.3%)	15025.6 (14.1%)	9231.6 (8.7)		
H.Organic carbon	Low	Medium	High		
Area in ha (%)	Majority of the study area rated under low OC status				
I. CEC/BS/AWC	Low	Medium	High		
Area in ha (%)	Cation exchange capacity (CEC), base saturation (BS) and available water holding capacity (AWC) status evaluated to be low to medium in majority of the soils of study area				
J. Misc. area in ha (%)	919.5 (0.9%)				

Results revealed that around 22.2% area is highly suitable (S1), 8.7% moderately suitable (S2), 59.3% marginally suitable (S3) and 8.9% area evaluated to be under presently not suitable (N1) class for mango cultivation (Fig. 2 and Table 3). Similar findings were reported by Rajesh *et al.* (2018), Anil Kumar *et al.* (2019) and Srinivasan *et al.* (2020).

Soil-site Suitability for Guava. Guava (*Psidium guajava* L.) is considered as one of the nutritious fruits in India as it contains good amount of calcium, phosphorus and vitamin C. It is grown as tropical fruit. It comes up well upto an altitude of 500 m above MSL. About 1000 mm annual rainfall received during rainy season is sufficient for its growth. The crop is tolerant to high temperature and drought conditions. It can withstand as high as 46°C temperature during summers but very susceptible to severe frost. Optimum temperature for its growth and development is between 23 to 28°C. It can thrive well on all types of soils ranging from alluvial to lateritic. It can come up even under shallow as well as poorly drained soils. It can tolerate high salinity (EC upto 8-9 d Sm^{-1}) and can be grown on a pH range from 4.5 to 8.2. Results revealed that about 22.2 and 54.3% area comes under class S2 and S3, respectively for guava cultivation (Fig. 3 and Table 3). Since, majority of the soils having moderately alkaline soil pH (8.0-8.5), slightly saline conditions and low OC content which limits the suitability groupings to class S2 and S3. Area under class N1 constitutes to 13.9%, and may be attributed to water logging/ poor drainage, sodicity/salinity, calcic layer and soil texture problem. Our research findings are in close agreement with the findings of Singh and Mishra (2012) and Baloda *et al.* (2014).

Soil-site Suitability for Citrus. Citrus grows well in tropical and subtropical climates and can withstand occasional light frosts. It requires an average temperature between 16-20°C for its good growth. It can be grown on almost all types of soil having adequate soil aeration besides sufficiently permitting the root penetration upto the desired depth. Deep, loamy, well-drained soils with pH range 5.5 to 7.5 are best suited for its cultivation.

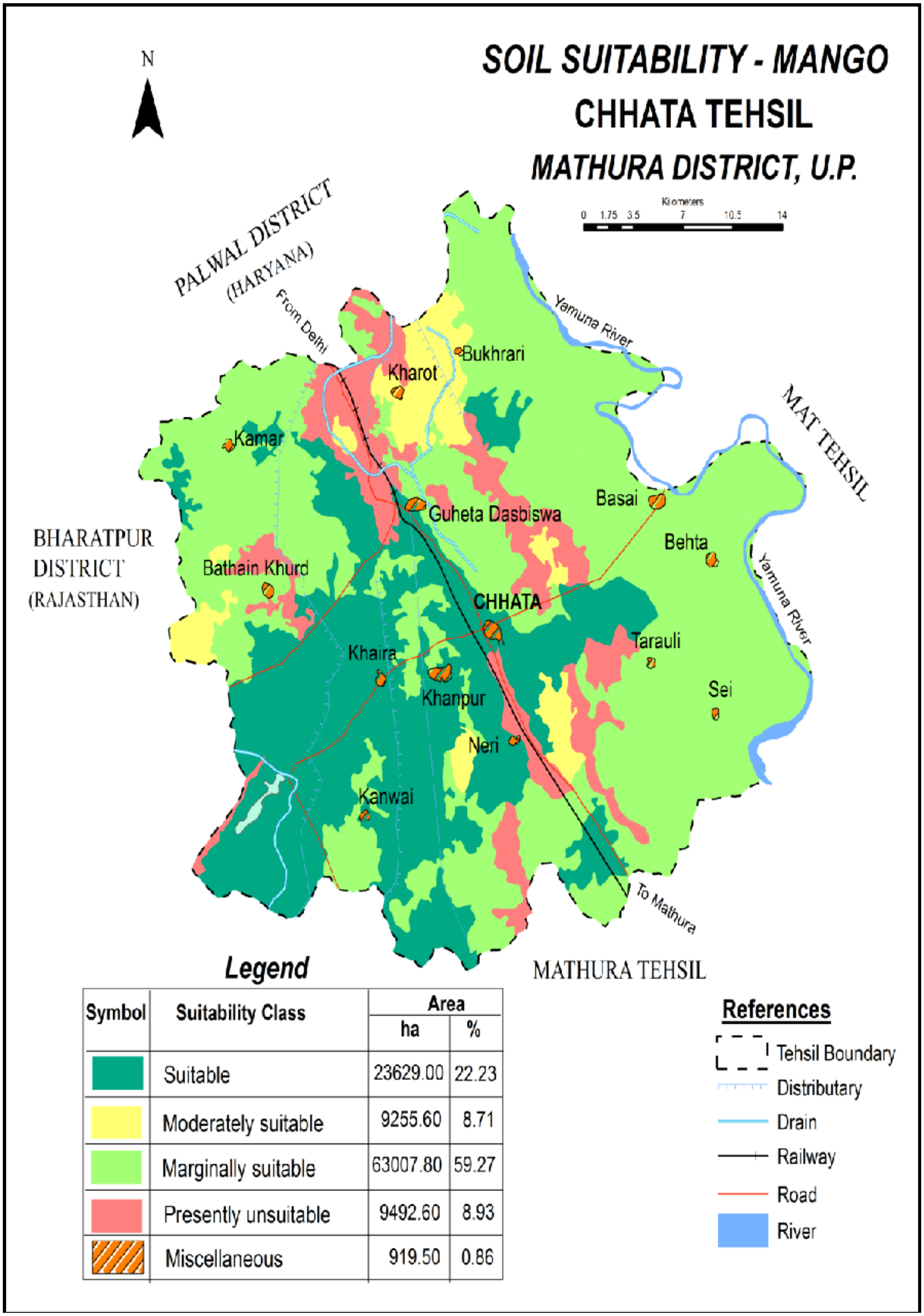

Fig. 2. Soil suitability map of mango.

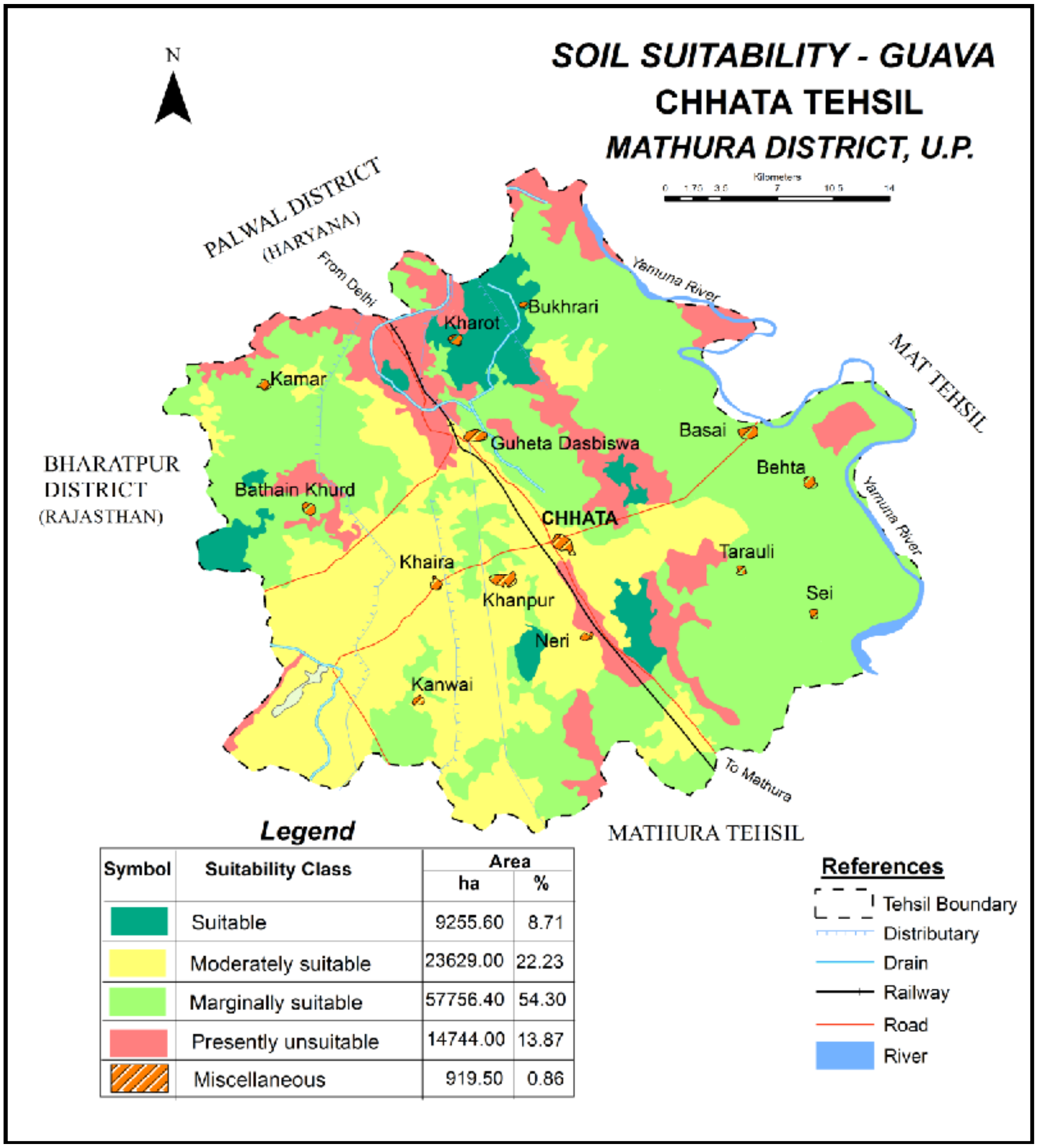

Fig. 3. Soil suitability map of guava.

Table 3: Soils under different suitability classes for major fruit crops.

Suitability class	Fruit crops				
	Mango	Guava	Citrus	Ber	Papaya
Highly suitable (S1)	23629.0 (22.2%)	9255.6 (8.7%)	-	9255.6 (8.7%)	64720.0 (60.9%)
Moderately suitable (S2)	9255.6 (8.7%)	23629.0 (22.2%)	88349.0 (83.1%)	79093.4 (74.4%)	23629.0 (22.2%)
Marginally suitable (S3)	63007.8 (59.3%)	57756.4 (54.3%)	11523.6 (10.8%)	2292.0 (2.2%)	-
Presently not suitable (N1)	9492.6 (8.9%)	14744.0 (13.9%)	5512.4 (5.2%)	14744.0 (13.9%)	17036.0 (16.0%)
Permanently not suitable (N2)	-	-	-	-	-
Miscellaneous	919.5 (0.9%)	919.5 (0.9%)	919.5 (0.9%)	919.5 (0.9%)	919.5 (0.9%)

-Particular crop does not qualify in that class due to soil-site characteristics limitations

It can be grown even on sandy loam soils with proper care and management. Saline or alkaline soils having lime nodules are not suitable for its cultivation. Results reveal that major part of the study area (83.1%) comes under soil suitability class S2 while, 16.0% area under class S3 and N1 (Fig. 4 and Table 3). The research findings closely follow the suitability criteria laid down by the Sys *et al.* (1993) and modified by Naidu *et al.* (2006).

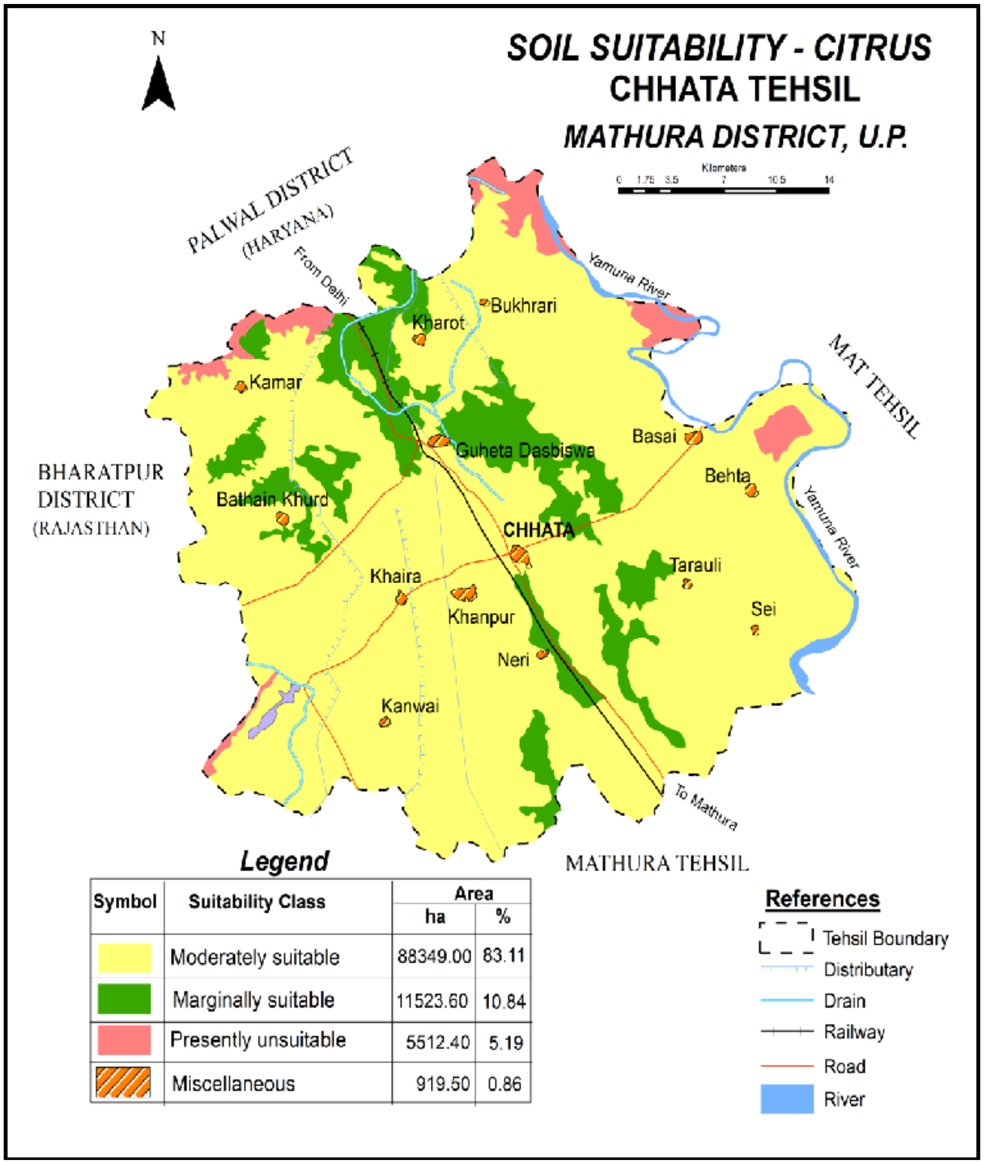

Fig. 4. Soil suitability map of citrus.

Soil-site Suitability for Ber. Ber is an important fruit crop of arid region due to its drought tolerance ability. It can flourish in areas receiving 400-500 mm rainfall. It prefers 28-32^{o}C temperature for its vegetative growth. It is mainly cultivated on poorly fertile sandy soils but the well drained loamy sands to loam soils are highly suitable for its cultivation. However, it is sensitive to highly saline/sodic soils but can tolerate sodicity upto certain degree. Results indicated that large part of the study area (74.4%) falls under suitability class S2 while, only 8.7% area evaluated to be class S1 for its cultivation (Fig. 5 and Table 3). Similar results were reported by Srinivasan *et al.* (2020).

Soil-site Suitability for Papaya. Papaya is a tropical fruit crop and comes up well in the mild sub-tropical regions also at an altitude upto 1000 m above MSL. Night temperature below 12-14^{o}C during winter season affects its growth and production severely. It is very sensitive to frost, strong winds and water stagnation. Deep, well drained sandy loam soil is ideal for its cultivation. Ideal soil pH is 6.0-6.6 but can be grown in a pH range of 5.0-6.6. Results revealed that majority of the soils of the study area evaluated to be under highly suitable (60.9%) followed by moderately suitable class (22.2%) for its cultivation (Fig. 6 and Table 3). Our research results are in close agreement with Sys *et al.* (1993).

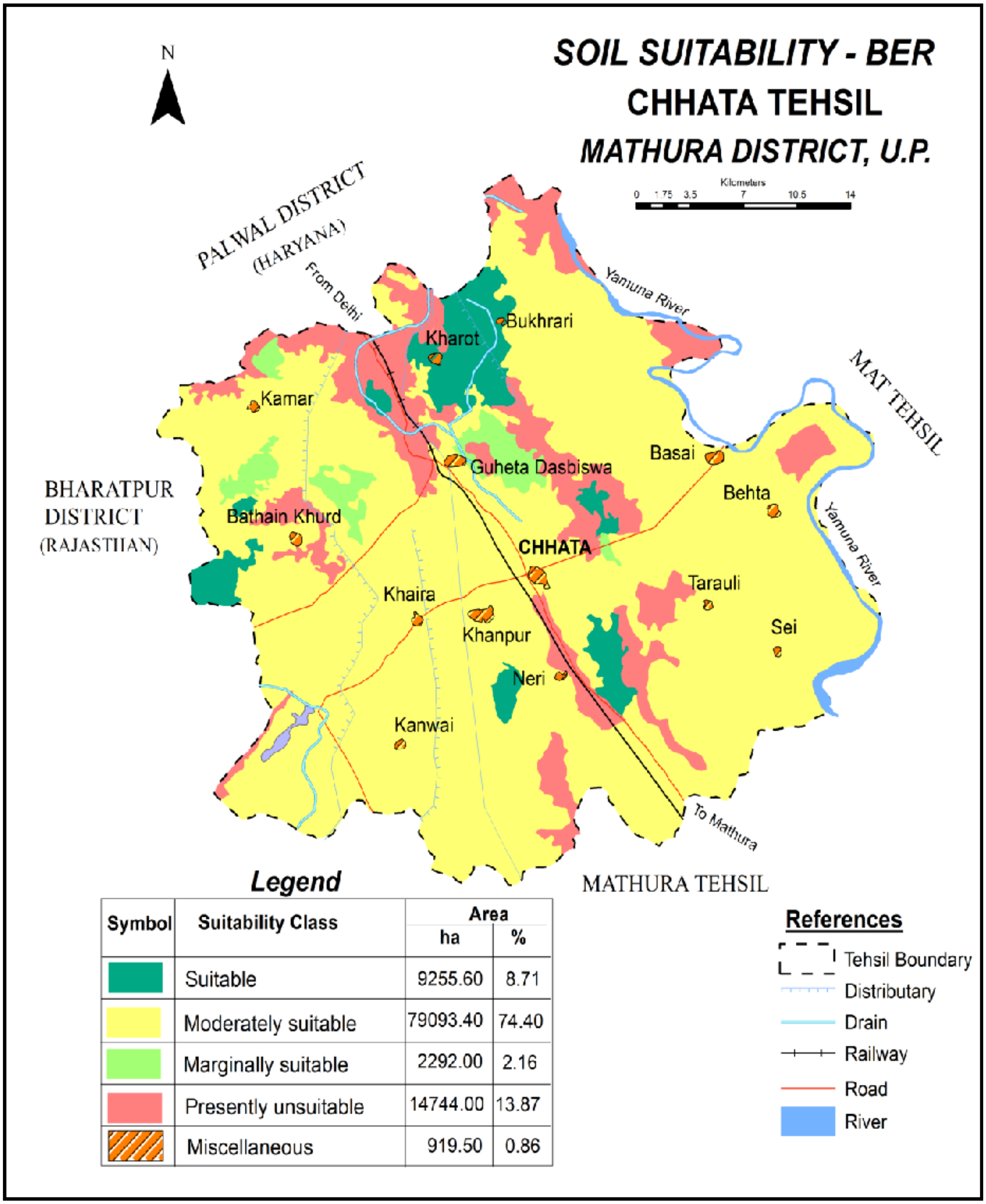

Fig. 5. Soil suitability map of ber.

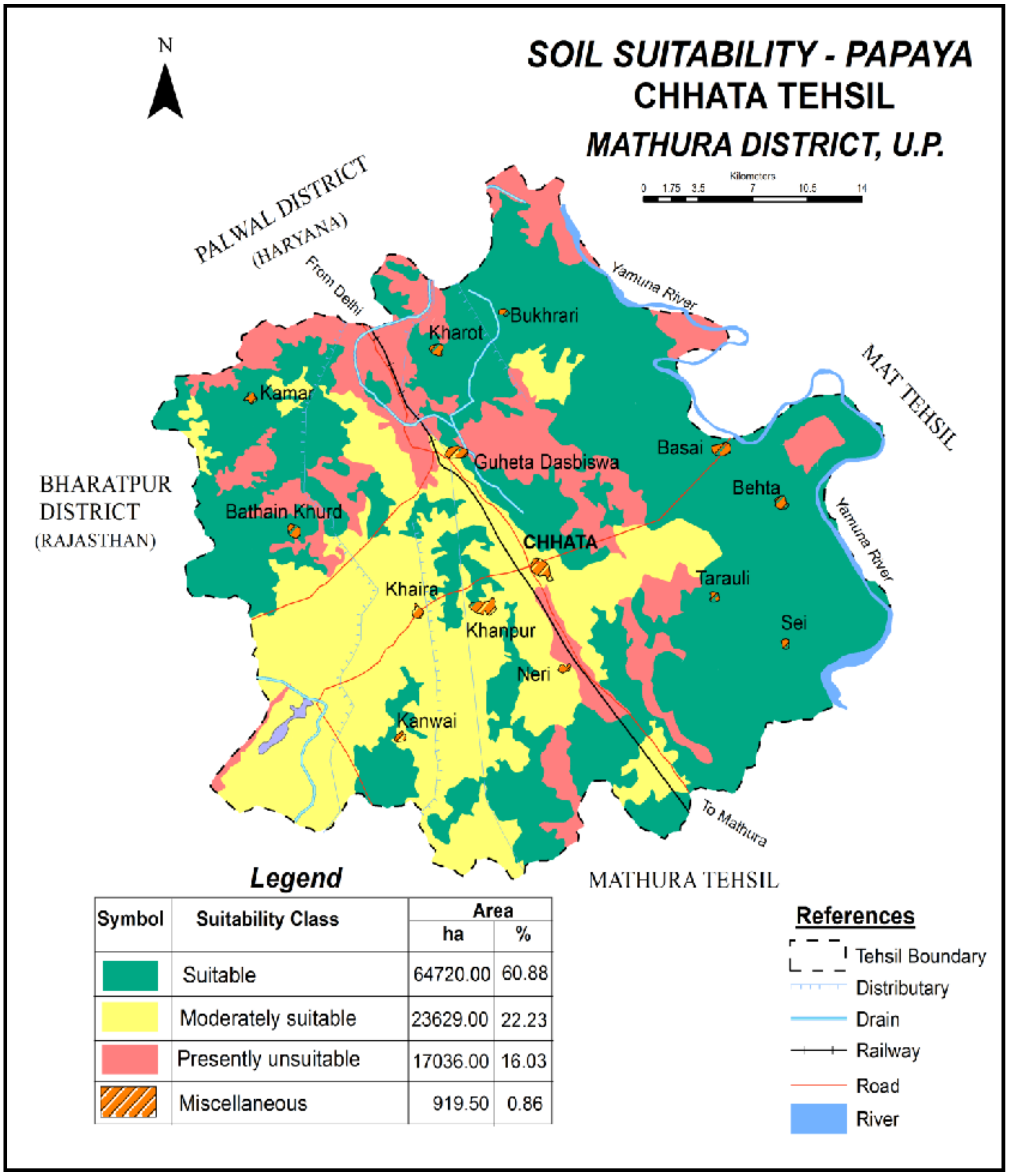

Fig. 6. Soil suitability map of papaya.

CONCLUSION

The study aims to evaluate the actual soil and site parameters which affect the suitability of various fruit crops for sustainable production. The most prominent soil parameters include texture, depth, slope, EC, pH, OC content, erosion and drainage while, rainfall and temperature are the most important climate parameters that affects the suitability of an area for crop production. Soils of the study area are very deep except Barsana soil series, slightly acidic to strongly alkaline in reaction, non-saline to saline, low in organic carbon and low to medium in CEC and base saturation. Soil suitability evaluation reveals that among the fruit crops, papaya and mango have maximum area *i.e.*, 60.9 and 22.2%, respectively under highly suitable class (S1). However, area under moderately suitable class (S2) observed to be highest for citrus (83.1%) and ber crop (74.4%) cultivation. About 59.3 and 54.3% area evaluated to be under marginally suitable class (S3) for mango and guava cultivation. Presently not suitable class (N1) soils evaluated to be maximum (16.0%) for papaya cultivation while, minimum (5.2%) for citrus cultivation.

Soil suitability maps of fruit crops could be of immense helps for effective implementation of technological interventions designed to achieve higher productivity. Besides, these are also helpful in developing strategies for proper soil and water conservation measures, and in adoption of best management practices. Further, mapping of the suitable areas may pave the ways for effective implementation of the policy decisions for horticulture development in the area oriented especially towards the fruit crops production.

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