Original Research Article

Evaluation of the Suitability of Horticultural Crops Under Prevailing Environmental Conditions - A Case Study of Punjab

ABSTRACT

Alternate land use options such as horticultural crops help in ensuring efficient land resource utilization. Thus, it is essential to evaluate the agri-environmental conditions for economically viable and sustainable horticultural production. A study was carried out for land use planning of Rajpura block in Patiala district of Punjab. Under this study, soil-site suitability of horticultural crops were evaluated by considering key soil parameters such as texture, depth, slope, EC, pH, organic carbon content, erosion, and drainage, and climate factors *viz.*, rainfall and temperature, etc. Soil site suitability of fruit cops revealed that approximately 45 to 60% study area found to be suitable for mango, banana, sapota and citrus whereas, about 50% area found to be moderately suitable for grapes, guava and pomegranate. likewise, soil-site suitability of vegetables such as potato, cabbage and tomato revealed that about 50.8% area of the block evaluated to be suitable for cabbage whereas, 34.36% and 30.8% for tomato and potato, respectively whereas, 51.67% area found to be marginally suitable for potato cultivation. Hence, it can be concluded from this study that the evaluation of soil suitability of horticultural crops is must to enhanced land resource management, sustainable land use planning and livelihood security of farmers.

Keywords: *Horticultural crops, land resources, soil suitability, land use planning and livelihood security.*

1. INTRODUCTION

Sustainable resource management considered as one of the most prominent issues in agriculture. Thus, effective land management necessitates appropriate land use planning (Geetha *et al*., 2019). Interplay between the economic sustainability and the environmental impact relies on management of its land resources (Rajesh *et al*., 2019). Therefore, evaluating land for agricultural planning involves a site-specific assessment of crop suitability. Crop suitability

evaluation refers to the determining of suitability of a particular type of land based on the growing conditions required for a specific crop [Singh *et al*., 2018; Karthikeyan *et al*., 2019). The basic objective of assessing agricultural land suitability is to anticipate the potential and constraints of the land for crop cultivation [Pan and Pan, 2012; Abdel Rahman *et al*., 2016). Further, cultivating horticultural crops as an alternate land use options is essential to ensure the efficient utilization of land resources (Kumar *et al*., 2021).

The horticulture sector is one of the most important agricultural enterprises which, supports nutritional security, poverty alleviation and employment generation (De, 2017). The goal of horticulture is to enhance plant growth, yield, quality, nutritional value and resilience to pests, diseases and environmental pressures in plants. India is home to a wide array of commercially important horticultural crops, with 30.4% of the country's GDP stemming from horticulture. India ranks second, following China, in the production of both fruit and vegetable groups (Horticultural Statistics at a glance, 2017). It is projected that by 2030, the demand for fruits and vegetables will surge to 110 and 180 million tonnes, representing a 155% and 95% increase, respectively from the base year 2000 (Vision-2023, 2011). The production of fruits has risen from 50.9 million tonnes to 97.35 million tonnes and vegetables from 101.2 million tonnes to 184.40 million tonnes between 2004-05 and 2017-18. The fruit-crop-based horticulture production system is economically feasible and readily adaptable (Chundawat, 1993; Chadha, 2002). Integrating annual field crops with fruit crops leads to higher yields and incomes (Osman, 2003). The productivity of fruits and vegetables is crucial as they offer greater monetary returns than cereals per unit of land (Yedage *et al*., 2013). Among the potentially profitable tropical agricultural products are horticultural commodities, particularly vegetables and fruits (Hamdan and Rahman, 2015). Moreover, it is recognized as a promising sector to enhance farm income, ensure livelihood security and generate foreign exchange through exports (Jha *et al*., 2019).

Keeping the economic viability of horticulture production system in mind the present study, *"Evaluation of the suitability of horticultural crops under prevailing environmental conditions - a case study of Punjab*" is intended to highlight the relevance of soil-site characteristics of an area to ensure sustainable horticultural development and livelihood security of the farmers without compromising the soil and environment health.

2. MATERIAL AND METHODS

2.1 Study area

Rajpura block is situated within the latitudinal range of 30°24'50" to 30°39'16" N and the longitudinal range of 76°25'56" to 76°49'14" E, and covers an area of 283.15 km^2. It is located in the north-eastern region of the Patiala district in Punjab, at an altitude varying from 200 to 300 meters above the mean sea level, and is enclosed by Ghanaur and Patiala blocks towards the southeast (Fig.1). The climate of the area is characterized as semi-arid and warm, predominantly dry with warm summers and cold winters, except for the monsoon season. The mean annual temperature recorded 23.2 °C whereas the mean maximum temperature and the mean minimum temperature were recorded 29.8 °C and 16.6 °C, respectively. The mean annual rainfall was recorded about 758 mm.

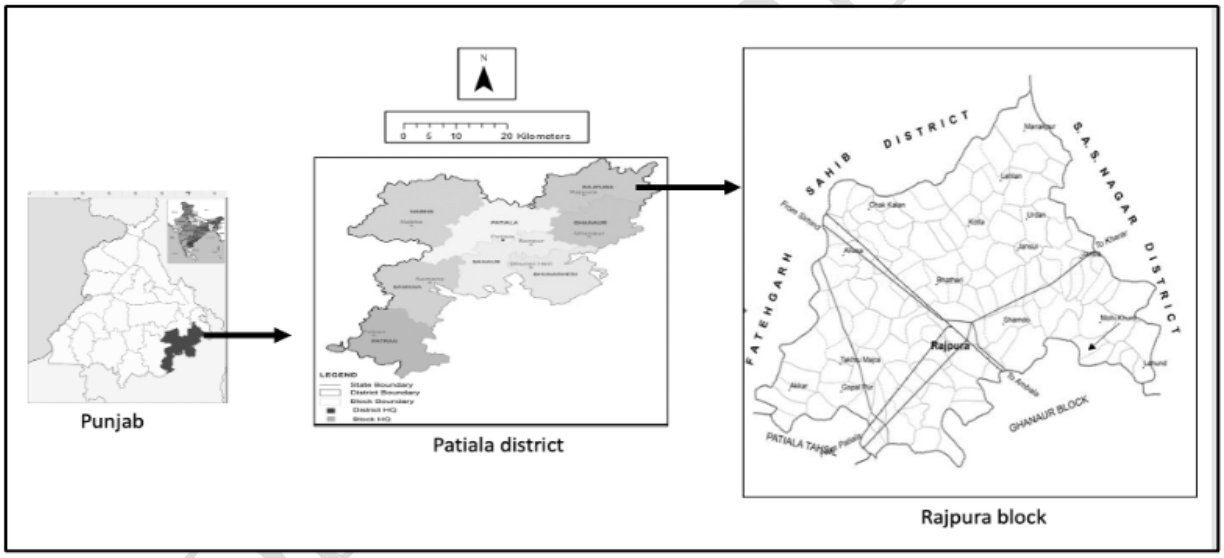


Fig. 1. Location map of Rajpura block, Patiala district, Punjab

2.2 Land use

Agricultural activities are dominant in the area as about 87% of the entire geographical is under agricultural land uses. Rice, wheat, sugarcane, maize, potato, onion, cauliflower and various other vegetables are cultivated in this block but primarily dominated by rice-wheat system.

2.3 Ground water resources

According to the 2013 assessment of Dynamic Groundwater Resources, the Rajpura block is classified as Over-Exploited (AMMP, 2017). The block has a total Ground Water Resources available is 2421.02 million cubic meter (mcm) and total potential granular zones available are 72 m upto a depth of 300 m. Majority of the land area being irrigated through tube wells.

2.4 Assessment of soil suitability for different crops

The determination of the relative suitability of crops were established by analysing soil site attributes and crop requirements, utilizing predefined suitability criteria as referenced in previous studies (Naidu *et al*., 2006; Sys, 1985; Sehgal, 1996). The concept of land utilization types for land evaluation, proposing a classification system for land based on its intended use (FAO, 1976). There are two orders viz., S for suitable lands and N for unsuitable lands, each indicating the level of suitability. Furthermore, order S is sub-classed into S1, S2, and S3, while under order N into two sub-classes i.e., N1 and N2, reflecting various degrees of suitability within each order. The assessment of classes within the Orders is conducted by evaluating the constraints imposed by factors such as climate (c), topography (t), wetness (w), salinity (n), soil fertility (f), and physical soil limitations (s).

2.5 Remote sensing and GIS

The crop suitability maps were generated in GIS environment.

3. RESULT AND DISCUSSION

3.1 Physiography and soils

The block is located within alluvial plains of the Ghaggar River. The parent material within the block consists of alluvium that originated from the sedimentary bed of the Shivalik range. Alluvial plain is categorized into old alluvial and recent alluvial plains with nearly level (0-1%) to very gently (1-3%) slopes. The soil surface properties of the block have been analysed (Table 1). The soils are very deep, somewhat excessively drained to somewhat poorly drained and loamy sand to silty clay soils. Soil limitations include drainage, alkalinity, salinity, sodicity,

soil texture and poor soil fertility. Major soils are medium in organic carbon content, low to high in nutrient holding capacity. Cation exchange capacity (CEC) of the soils of block varies from 5 to 27 Cmol (p+) kg^{-1} (Meena *et al*., 2024).

Table1. Soil surface properties of Rajpura block, Patiala district, Punjab

Parent material	Landform	Slope	Depth	Drainage	Surface Texture	Soil pH	Soil salinity [EC(dsm^{-1})]	Organic carbon (%)	CEC Cmol (p+) kg-1	Base saturation (%)	$CaCO_3$ (%)
Alluvium	Old alluvial plains and recent alluvial plains	0-1 and 1-3%	Very deep	Some-what excessively drained to some-what poorly drained	loamy sand to clay loam	7.3 to 8.6	0.01 to 0.9	0.3 to 1.2 %	5 to 27	87 to 98	0.2 to 0.9

3.2 Soil-site suitability for fruit crops

3.2.1 Soil-site suitability for Mango (Mangifera indica)

Mango known as the national fruit of India and thrives particularly well in tropical and subtropical climates. It is cultivated in almost every state of India, contributing to about 56% of the global mango production. Cultivation of the mango fruit necessitates specific soil conditions such as a depth exceeding 200 cm, comprising sandy loam, silt loam, clay loam, and loam textures, with the ability to sustain a pH level of up to 8.7 through effective nutrient management. The soil composition within the region has been meticulously analysed to align with the requirements of mango cultivation, with the distribution across various suitability units (Fig. 2). About 50.8% areas found to be suitable for mango cultivation, while 33.51% and 1.68% moderately and marginally suitable, respectively.

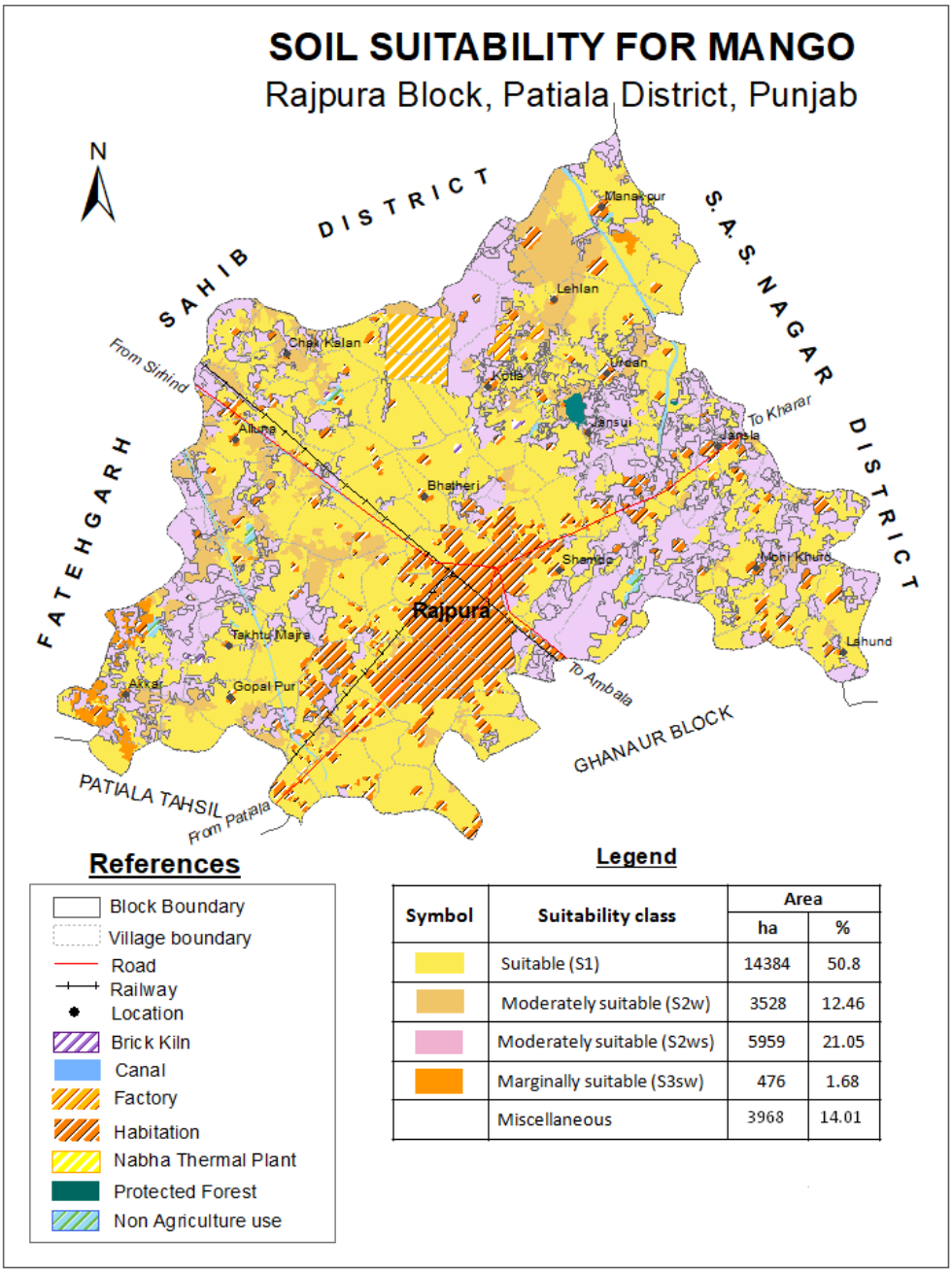


Fig. 2. Soil site suitability for mango

3.2.2 Soil-site suitability for grapes (Vitis vinifera)

Grape is considered as berry type fruit and non-climacteric in nature. Regions with an annual rainfall exceeding 100 cm are deemed most suitable for grape cultivation. Generally, higher yields of grape can be obtained from deep, fertile soils. Ideal conditions for grape cultivation include a soil depth ranging from 100 to 150 cm, with textures such as sandy loam,

silt loam, clay loam, and loam, as well as well-drained soils. The optimal temperature range is between 25 °C and 30 °C. To achieve maximum crop production, a mean relative humidity of 50–60% is ideal. Soil-site suitability characteristics evaluation for grape cultivation revealed that 49.91% area in the block found to be moderately suitable while 34.36% is suitable and 1.68% is marginally suitable for its cultivation (Fig. 3).

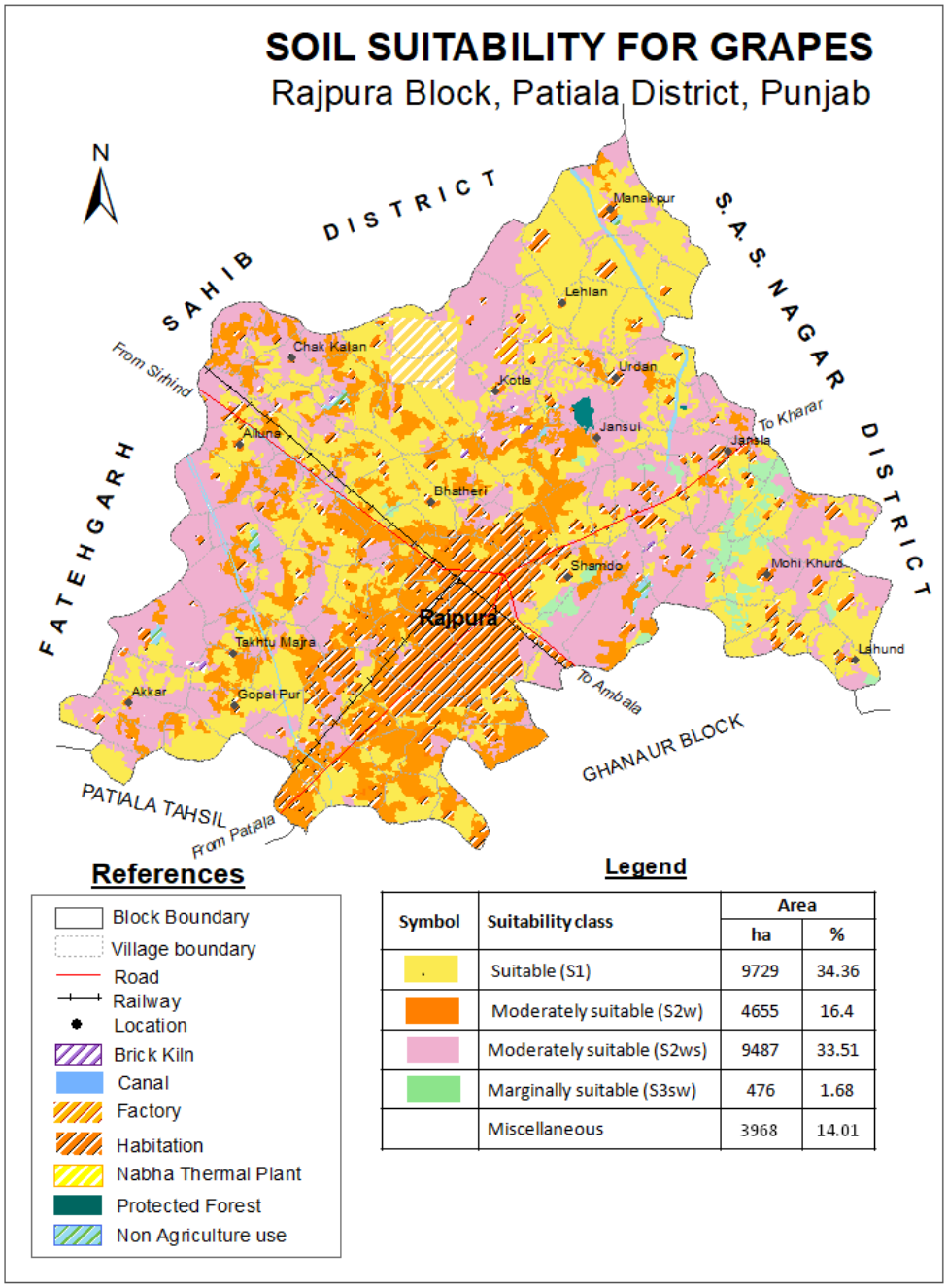
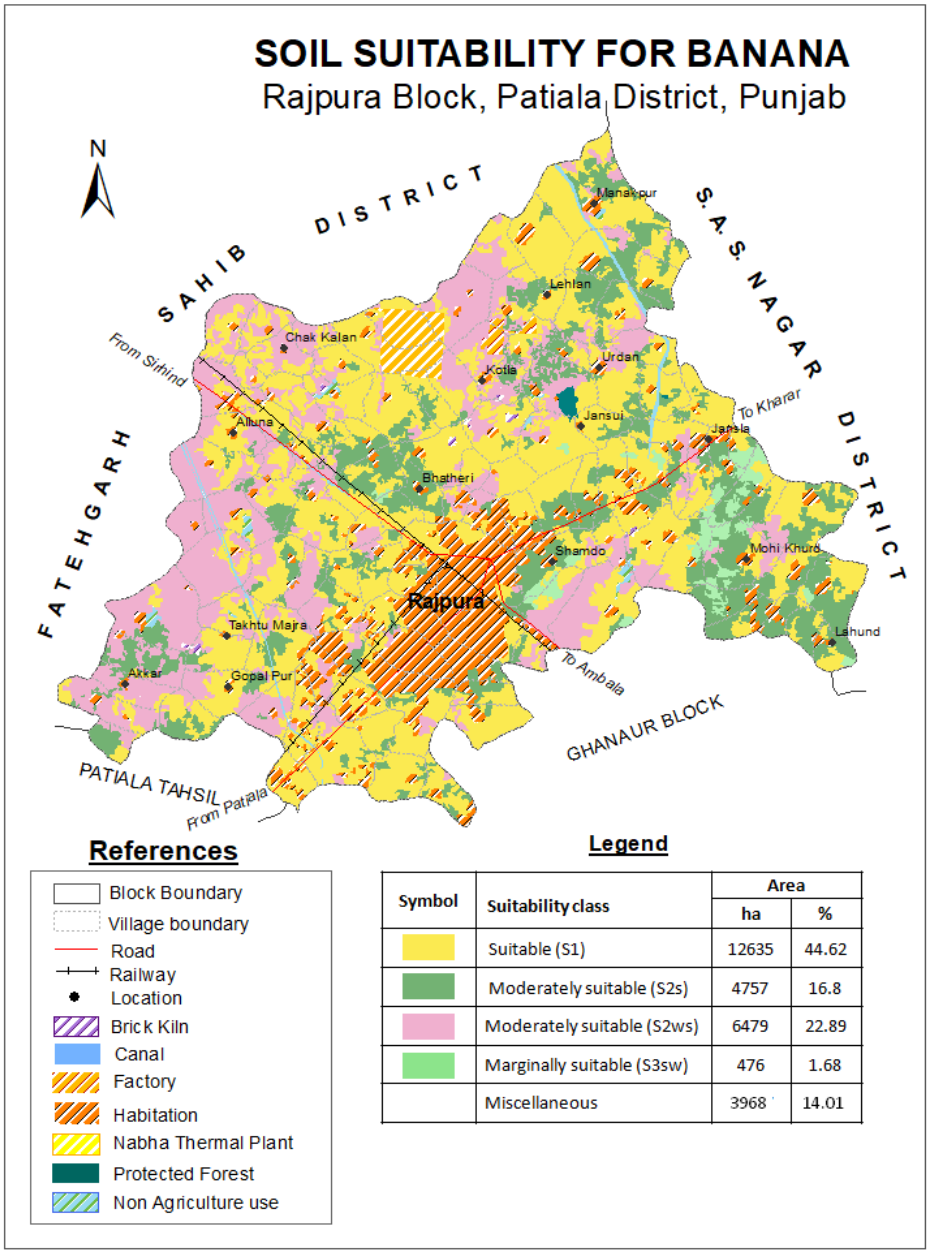


Fig. 3. Soil site suitability for grapes

3.2.3 Soil-site suitability for banana (*Musa paradisiaca* L.)

Banana is considered one of the most popular fruits due to health benefits. Optimal conditions for banana cultivation encompasses soil types that are deep, rich in loam, slightly salty clay loam, with a pH in the range of 6 to 7.5. Soil suitability revealed that 44.62% of the block area found to be suitable for banana cultivation while, 39.69% area evaluated to be moderately suitable. However, only1.68% area found to be marginally suitable for banana the cultivation under the existing soil-site conditions (Fig. 4).



Symbol	Suitability class	Area	
		ha	%
	Suitable (S1)	12635	44.62
	Moderately suitable (S2s)	4757	16.8
	Moderately suitable (S2ws)	6479	22.89
	Marginally suitable (S3sw)	476	1.68
	Miscellaneous	3968	14.01

Fig. 4. Soil site suitability for banana

3.2.4 Soil-site suitability for sapota (Manilkara zapota)

Sapota commonly referred to as *Chiku*, is a tropical crop predominantly cultivated in India for its fruit. The crop thrives in various soil types, particularly deep alluvium, sandy loam and well-drained soils with pH 6.0 to 8.0. Conversely, shallow clay soils with underlying hard pan or high calcium contents are deemed unsuitable for sapota cultivation. The soils of the block have been interpreted to assess their appropriateness for sapota cultivation indicated that 44.62% area found to be highly suitable, while 39.69% evaluated to be moderately suitable for its cultivation (Fig.5).

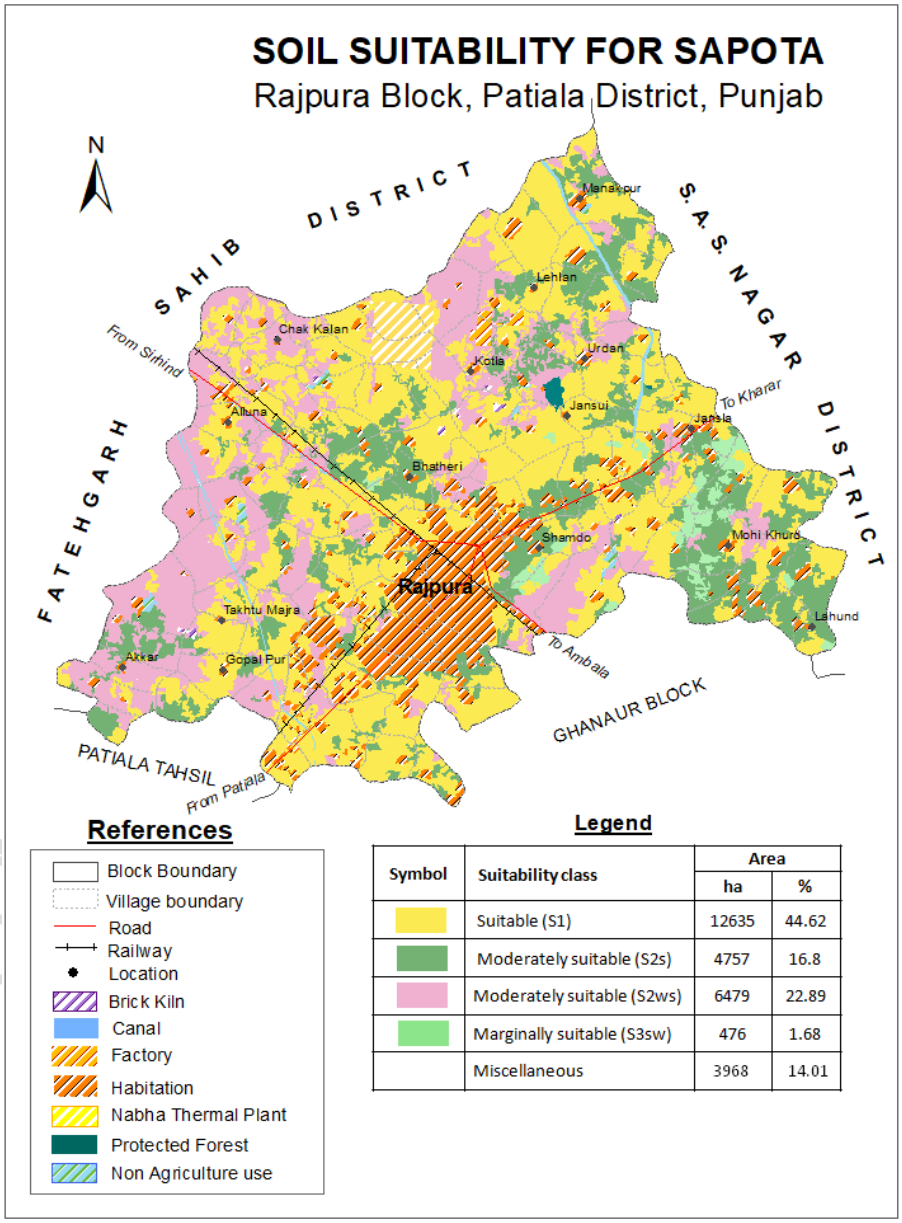


Fig. 5. Soil site suitability for sapota

3.2.5 Soil-site suitability for guava (Psidium guajava)

Globally, guava is cultivated in tropical and subtropical regions. It is abundant in vitamins A, B, and C. The fruits undergo processing to prepare jams, jellies and often serving as popular pastry fillings. The cultivation of guava requires deep soils exceeding 100 cm, encompassing textures such as sandy loam, silt loam, clay loam and loam, while also requiring soils devoid of salinity and alkalinity and possessing good drainage. The optimal temperature range for guava cultivation falls between 28°C to 32°C. Maximum crop yield reported with a growth period beyond 150 days (Bhargawa *et al*., 2023). Soil-site suitability evaluation revealed that 34% area found to be suitable for guava cultivation while, 50.31% area found to be moderately suitable for its cultivation (Fig. 6).

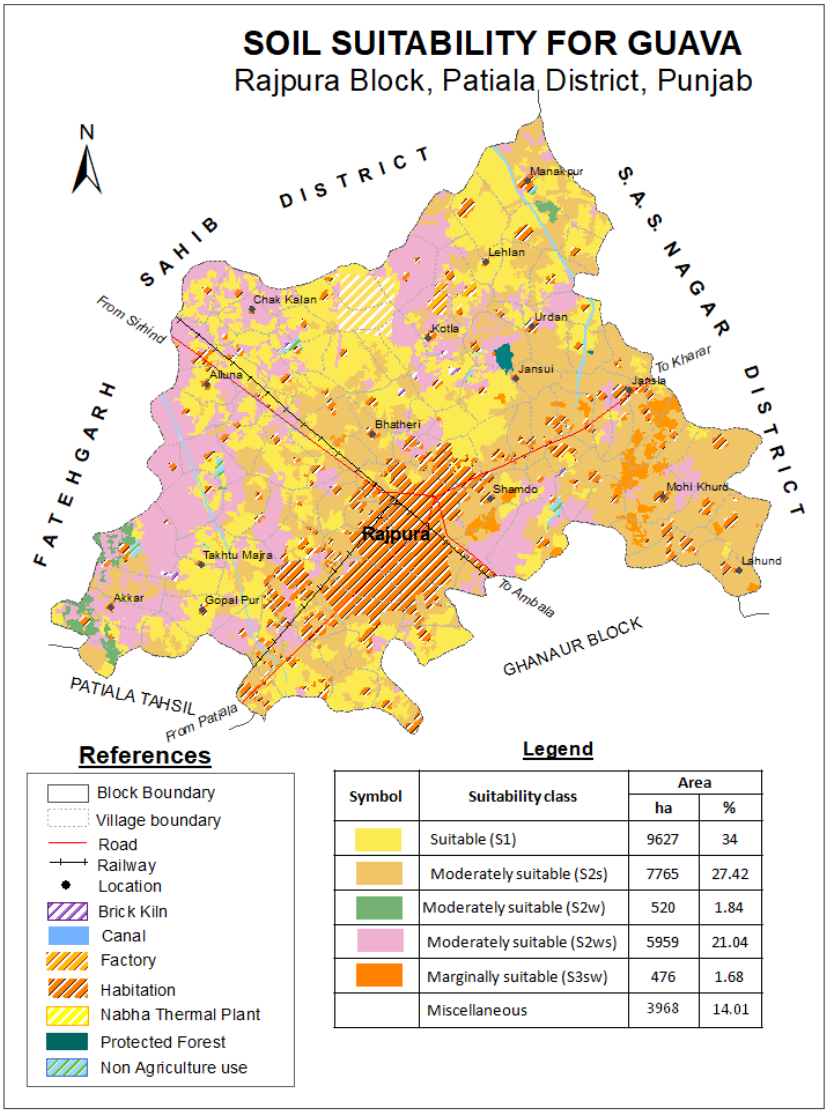


Fig. 6. Soil site suitability for guava

3.2.6 Soil-site suitability for pomegranate (Punica granatum)

Pomegranate shows adaptability to a wide range of climatic circumstances and exhibits resilience against drought. It holds the distinction as a beloved table fruit in tropical and subtropical regions [14]. It thrives both in lowlands and elevations scaling up to 2000 meters above mean sea level. It requires deep soils exceeding100 cm depth, encompassing textures like sandy loam, silt loam, clay loam and loam, free from salinity, alkalinity, and possessing good drainage. Optimal temperature conditions for pomegranate growth range from 30°C to 34°C. Evaluation of soil suitability indicated that about 34.36% area found to be suitable for pomegranate cultivation while, 49.95% area evaluated to be moderately suitable for its cultivation (Fig. 7).

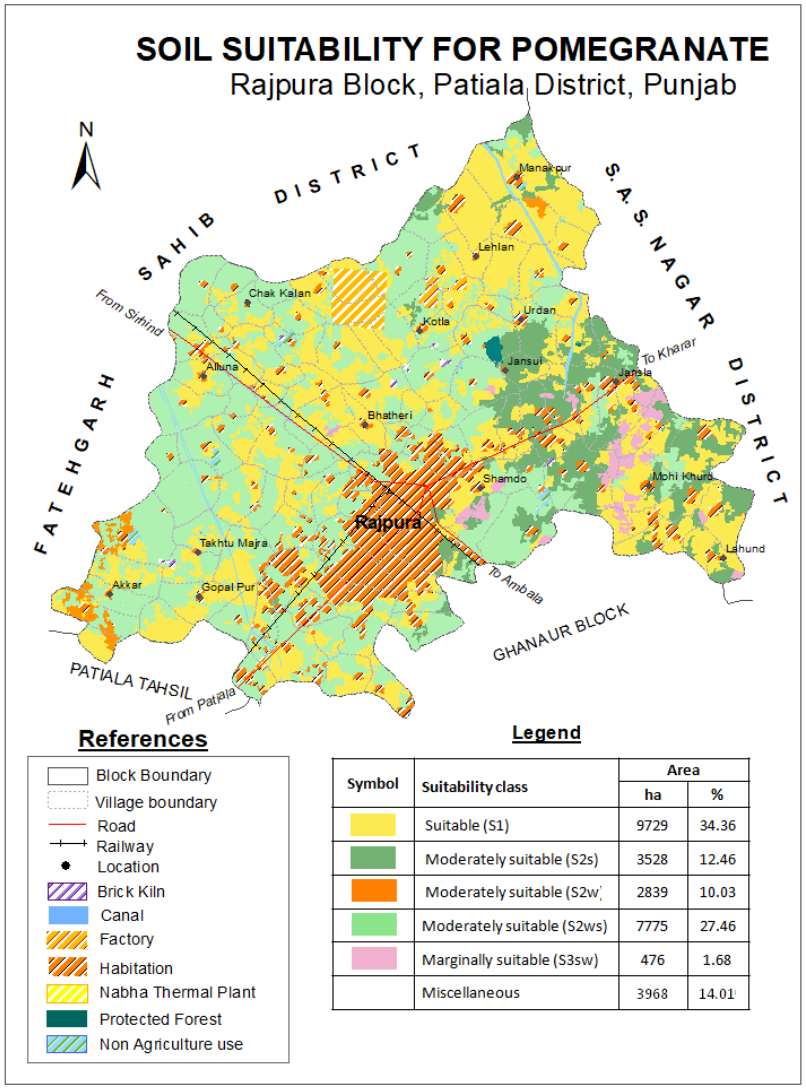


Fig.7. Soil site suitability for pomegranate

3.2.7 Soil-site suitability for citrus

Citrus cultivation requires soil depth exceeding 150 cm. Soils characterized by sandy loam, silt loam, clay loam or loam texture, devoid of salinity and alkalinity and possessing good drainage considered good for its cultivation. The soil suitability evaluation of the block indicated that 61.42% area found to be suitable while 22.89% evaluated to be moderately suitable for citrus cultivation (Fig. 8).

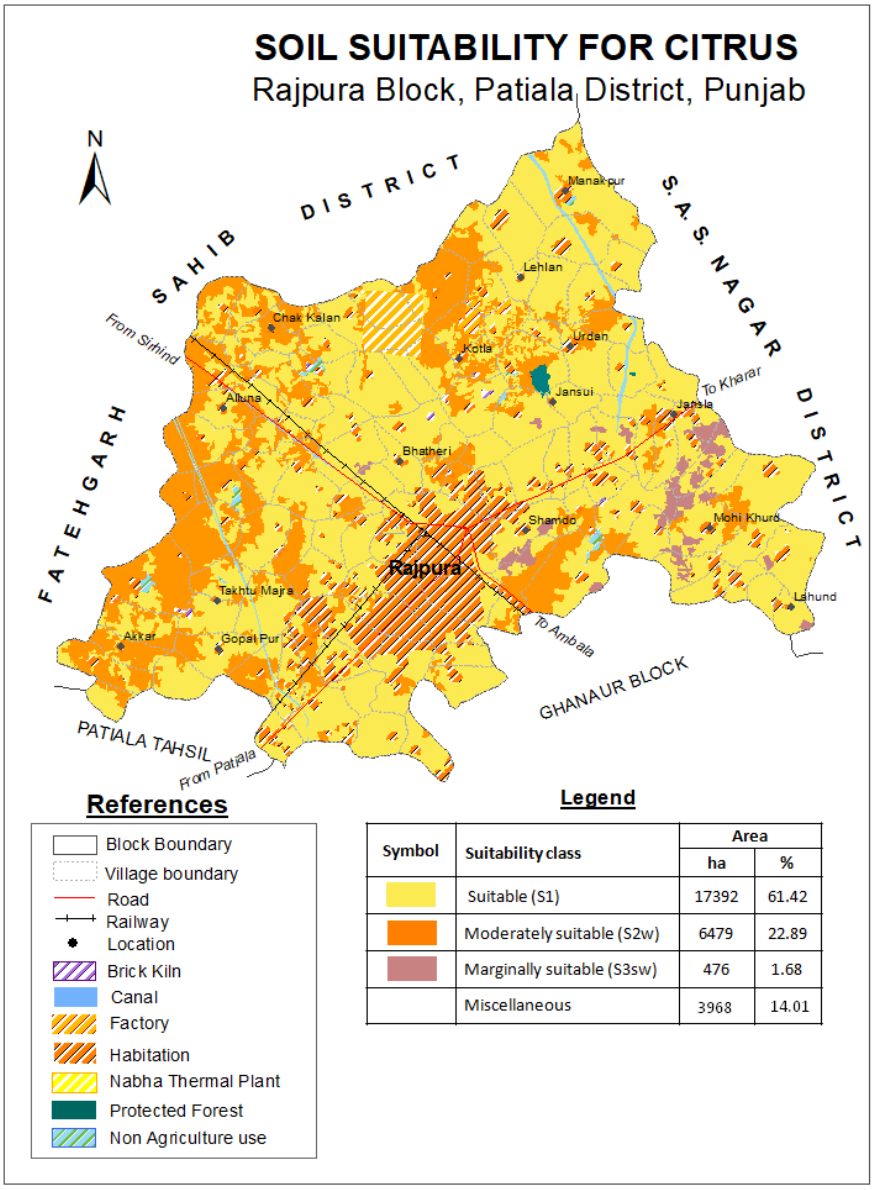


Fig. 8. Soil site suitability for citrus

4. CONCLUSIONS

The cultivation of the horticultural commodities particularly the fruits are potentially profitable production system. The economic viability along with production sustainability helps not only the livelihood security but also the self-sufficiency and reliance of an area in production. Therefore, soil and site characteristics need to be evaluated for cultivation of different fruit crops. The study proposed suitability maps of various fruit crops depicting highly suitable, moderately, and marginally suitable areas in the block for various fruit crops. Besides, it also indicated not suitable areas on account of various soil physico-chemical constraints. The thematic crop suitability maps greatly assist the planners in effective implementation of strategies aiming to enhance productivity.

REFERENCES

1. Geetha, G. P., Veerendra Patel, G. M., Shruti, Y., Ramakrishna Parama, V. R. & Sathish, A. (2019). Land evaluation in halayapura1 micro watershed in Tumkur district of Karnataka, India, using remote sensing and geographical information system (GIS) tools. *Int. J. Chem. Studies*., 7(1), 84-94.

2. Rajesh, N. L., Kirana Kumara, V. Rajesh, Chandralekha, Ambika Bhandari, S. Deepika, Basavajyoti, Ambika, H. V. Rudramurthy, K. Basavaraj, U. Satishkumar & Desai, B. K. (2019). Land Suitability Evaluation for Legume Crops and Horticulture Crops in Paman Kallur-1 Micro-Watershed using Geospatial Techniques. *Int.J.Curr.Microbiol.App.Sci.,* 8(12), 1302-1317.

3. Singh, P., Upadhyay, R. K., Bhatt, H. P., Oza, M. P., & Vyas, S. P. (2018). Crop Suitability Analysis for Cereal Crops of Uttar Pradesh, India, *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci*., XLII-5, 353–360.

4. Karthikeyan, K., Nirmal, K., Ajit, G., Pushpanjali & Prasad, J. (2019). Assessment of soil site suitability for cotton farming in the semi-arid regions of Central India: An analytic hierarchy process, *Journal of the Indian Society of Soil Science*, 67(4), 402-410.

5. Pan, G. & Pan, J., (2012). Research in crop land suitability analysis based on GIS.*Computer and Computing Technologies in Agriculture*, 365, 314–325.

6. Abdel Rahman, M.A.E., Natarajan, A., & Hegde, R. (2016). Assessment of land suitability and capability by integrating remote sensing and GIS for agriculture in

Chamarajanagar district, Karnataka, India. *The Egyptian Journal of Remote Sensing and Space Science*, 19(1), 125-141.

7. Kumar, A., Mahapatra, S.K. & Surya, J. N. (2021). Soil Suitability of Some Major Fruit Crops for Sustainable Production in the IGP Region of India-A Case Study. *Biological Forum – An International Journal*, 13(1), 200-210.

8. De LC. (2017). Horticulture scenario in NE region of India. *International Journal of Agricultural Science and Research,* 7(2), 243–254.

9. Horticulture Statistics at a Glance. (2017). Horticulture Statistics Division, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Framers Welfare, New Delhi.

10. Vision 2030, (2011). Indian Council of Agricultural Research, New Delhi.

11. Chundawat, B.S. (1993). Intercropping in orchards. *Advances in Horticultural Science*, 2(2), 763- 775.

12. Chadha, K.L. (2002). Diversification to horticulture for food, nutrition and economic security. *Indian Journal of Horticulture*, 59(3), 209-229.

13. Osman, M. (2003). Alternate land use systems for sustainable production in rainfed areas. In: Agroforestry-potential and opportunities (eds. P.S. Pathak and Ram Newaj): pp 177-181.

14. Yedage, A., Gavale, R. & Jarag, A. (2013). Land assessment for horticulture (Pomegranate) crop using GIS and Fuzzy decision analysis in the Sangola taluka of Solapur District. *International Journal of Remote Sensing and GIS*, 2(3), 104-113.

15. Hamdan & Taupik Rahman. (2015). Land Suitability for Horticultural (Fruit) Crops Development in Mukomuko District, Bengkulu Province. *International Seminar on Promoting Local Resources for Food and Health*, 12-13 October, 2015, Bengkulu, Indonesia 259-264.

16. Jha, G.K., Suresh, A., Punera, B. & Supriya, P. (2019). Growth of horticulture sector in India: Trends and prospects. *Indian Journal of Agricultural Sciences,* 89(2), 314–321.

17. Aquifer Mapping and Management Plan. (2017). Patiala district Punjab, 1-117.

18. Naidu, L.G.K., Ramamurthy, V., Challa, O., Hegde, R. & Krishnan, P. (2006). Manual soil site suitability criteria for major crops. Tech. Bull. No. 129, NBSS&LUP, Nagpur (India), 118.

19. Sys, C. (1985). *Land Evaluation*; Part I, II and III. Agriclas, Publ.**7**, Ghent, Belgium.

20. Sehgal, J. (1996). *Pedology-concepts and applications*. First Edition, Kalyani publishers, New Delhi.

21. FAO (1976). A Frame Work of Land Evaluation. Soils Bulletin.32, FAO, Rome.

22. Meena, R.K., Vikas, Verma, T.P., Mahapatra, S.K., Surya, J.N., Lal, T., Yadav, R.P., Singh, S.K., Chandran, P., Dwivedi, B.S., Bhaskar, B.P. & Patil, N.G. (2024). Land Resource Inventory of Patiala district, Punjab on 1:10,000 Scale for Agricultural Land Use Planning. NBSS Publ. No. 1201. ICAR-NBSS&LUP, Nagpur, pp. 115.

23. Bhargava, M., Yadav, N., Patil, PL., Hebbara, M., Angadi, SS., & Meti, CB. (2023). Soil-site suitability assessment for major fruit crops in Ganjigatti sub-watershed (5B1A4F), Karnataka using remote sensing and GIS techniques. *The Pharma Innovation Journal*, 12(9), 994-1005.