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GIS BASED NATURAL RESOURCE MAPPING FOR CROP PLANNING IN UNA DISTRICT, HIMACHAL PRADESH

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ABSTRACT
Identifying suitable locations for agricultural products is a crucial area of study, as it is vital to determine optimal regions for crop productivity and sustainable farming practices. Horticulture is a national priority in Himachal Pradesh, as the region's hilly terrain is highly conducive to horticultural crop production and plays a crucial role in environmental conservation**.** The present study was conducted in the Una district of Himachal Pradesh to identify the suitable areas for fruit crop production in the district. Analysis of soil data, weather data and satellite data alongwith physiographic mapping was conducted. The analytical hierarchy process approach was adopted to derive the site suitability map, supplemented by data obtained from a survey based on a questionnaire. The study has delineated the potential suitable area for fruit production of Mango, Guava, Pomegranate, Citrus and Litchi in Una. The study highlights the necessity for developing suitable land use planning to optimize the productivity of fruits in highly suitable areas. Therefore, the study identified potential areas for fruit production and suggests that further policy to boost fruit production in Una district should be developed.

KEYWORDS: Una, Horticulture, Suitability Analysis, Fruit Crops, Potential Areas.

INTRODUCTION
Identifying suitable locations for agricultural products is a crucial area of study, as it is vital to determine optimal regions for crop productivity and sustainable farming practices [1]. Economically, countries must adopt sustainable agricultural policies and utilize their limited agricultural lands efficiently. Therefore, implementing regional agricultural crop planning and assessing land suitability for each crop is essential [2,3]. Assessing land suitability is vital for optimizing land use, as it takes into account both physical factors (such as soil, climate and topography) and socio-economic factors (including accessibility, workforce availability and market position) while also conserving environmental and natural resources [4]. Land suitability studies for various agricultural products have successfully identified suitable sites in different regions worldwide. Examples include sugarcane[5], maize [6], orange and pineapple in India [7], olive [8] and tobacco in China [9], avocado in Turkey [10], wheat and maize in Iran [11], winter wheat [4] and vineyard cultivation in Syria [12], and maize in Kenya [13]. These studies were conducted by utilizing the GIS-based AHP method.
The principles of sustainable development add complexity to land suitability analysis by requiring consideration of multiple criteria. This involves not only evaluating a land unit inherent capacity to support a specific use over time without degradation but also considering socio-economic and environmental conditions. Often, assigning relative weights to these diverse criteria is challenging. Therefore, adopting a technique that facilitates the estimation of these weights is necessary. One such technique is the Analytical Hierarchy Process (AHP) [14,15]. Given that land suitability analysis involves managing both spatial and attribute data across multiple layers, GIS can be utilized to integrate biophysical and socioeconomic characteristics for land evaluation. A multi-criteria evaluation tool can be developed to assist decision-makers in balancing the interests of various stakeholders. Therefore, integrating GIS with AHP in a multi-criteria land suitability analysis is expected to yield promising results.
Horticulture is a national priority in Himachal Pradesh, as the region's hilly terrain is highly conducive to horticultural crop production and plays a crucial role in environmental conservation [16]. Horticulture encompasses diverse cropping systems across all agro-climatic zones, offering healthy and nutritious food while generating employment and income for small-scale farmers, including women, who are often the primary producers. Himachal Pradesh benefits from favorable

agro-climatic conditions for horticulture development, but the main challenge lies in the scarcity of suitable land for cultivation. Therefore, conducting land suitability analysis and evaluation using GIS is crucial for identifying appropriate land for various fruit trees. Una district in Himachal Pradesh falls under the Sub-Montane and Low Hills Subtropical Zone, where the primary fruit crops are citrus, mango and litchi. Key factors influencing plant growth, either directly or indirectly, include temperature, humidity, rainfall and seasonal patterns. Mango, in particular, is well adapted to high summer heat [17].

Therefore, a land suitability map of the district Una of Himachal Pradesh was prepared to identify the suitable areas for growing fruit crops.

MATERIALS AND METHODS

Study Area: The study was conducted in five blocks viz. Una, Bangana, Haroli, Gagret and Amb of Una District, Himachal Pradesh. Una district is situated in the southwestern part of Himachal Pradesh, encompassing an area of 1,540 square kilometers. The district is located between 31°17'52" to 31°52'00" N Latitude and 75°58'02" to 76°28'25" E Longitude, with an elevation ranging from 332 to 1162 meters above sea level. The study area is characterized by a semi-hilly terrain with low hills. The location map of the study area is shown in Figure 1.

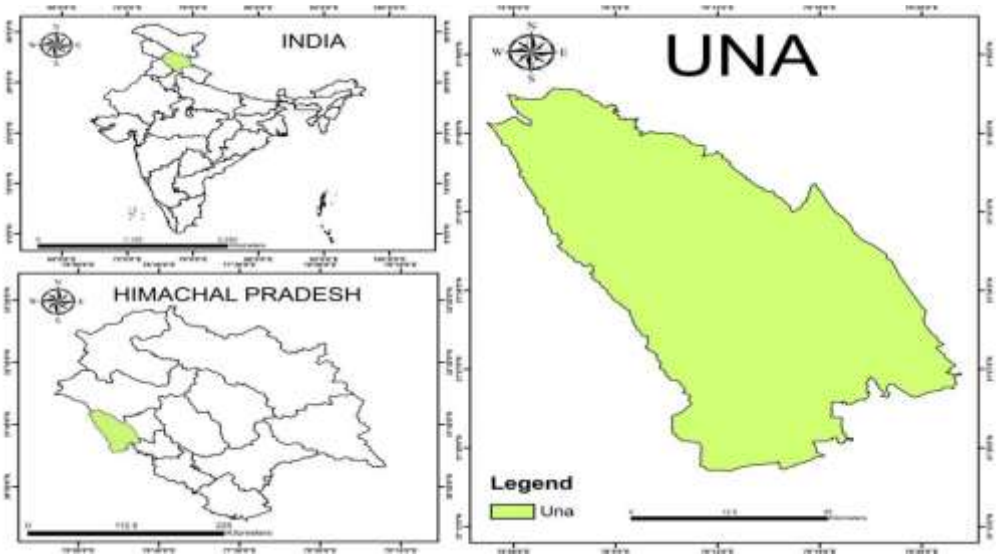

Fig. 1 Location Map of Study Area

MATERIALS AND METHODS

Data were collected to acquire the location of the different sites such as built-up, river, agriculture etc. The data collected included the geographic coordinates of the location, soil samples from agricultural land. The information and location were noted with the help of maps and Global Positioning System (GPS). The weather data used in the study was acquired from three weather stations Bhakra Beas Management Board, Bhakra, Krishi Vigyan Kendra (KVK), Berthin and Regional Research Station, Akrot. The satellite data was downloaded in two forms. The Sentinel-2 data were downloaded from the ESA (European Space Agency) Copernicus open access hub and the CartoSat-1 (IRS-P5) data were downloaded from the BHUVAN website.

METHODOLOGY

Preliminary survey of the different land uses of various blocks of Una district was conducted for ground truthing of data. The location of the different land uses was recorded with a Global Positioning System (GPS). The soil samples from the agricultural field and barren land were collected 60 in number. The sample locations were selected according to the 5x5 grid map prepared. Total number of grid boxes selected were 60. For each grid, 4 samples were selected and then mixed with each other to provide a representative sample for the specified grid.

The Sentinel-2 satellite data obtained for the year 2021 were utilized based on a preliminary survey. ArcMap 10.6.1 was used for map generation, LULC delineation and topographical examination of the study area. A survey questionnaire was prepared for the perception data collection of the fruit growers as well as the non-fruit growers.

Analytical Hierarchy Process (AHP) tool was run in Arc-GIS 10.6 software for integrating different parameters studied. A parameter-wise comparison matrix was calculated for creation of the final suitability map as well as the nutrient availability map. The different parameters were ranked individually by different field experts which were then averaged to remove bias from the AHP process.

A step wise illustration of the preparation of land suitability map is shown in Figure 2. Table 1 shows the different factors selected for land suitability analysis by AHP method. Table 2 and 3 shows the preference matrices for mapping of suitability map and preference matrix for mapping of nutrient availability map respectively.

Table 1. Factors Selected for Suitability Analysis through AHP

Weather Parameters	Minimum Temperature
	Maximum Temperature
	Rainfall
Soil Parameters	pH
	Electrical Conductivity
	Organic Carbon
	Nitrogen
	Phosphorus
	Potassium
Physiographic Parameters	Slope
	Elevation
	Aspect
	Hillshade
	LULC

Table 2. Preference Matrices for mapping of Suitability map

	Maximum Temperature	Minimum temperature	Slope	Aspect	Elevation	LULC	Hillshade	Nutrient availability parameters	Rainfall
Maximum Temperature	1	0.33	0.2	0.2	3	5	3	3	5
Minimum Temperature	3	1	0.2	0.2	3	7	5	3	5
Slope	5	5	1	0.33	5	9	7	5	7
Aspect	5	5	3	1	7	9	7	5	9
Elevation	0.33	0.33	0.2	0.14	1	5	3	3	3
LULC	0.2	0.14	0.11	0.11	0.2	1	0.33	0.33	0.33
Hillshade	0.33	0.2	0.14	0.14	0.33	3	1	0.33	0.33
Nutrient availability parameters	0.33	0.33	0.2	0.2	0.33	3	3	1	3
Rainfall	0.2	0.2	0.14	0.11	0.33	3	3	0.33	1

Table 3. Preference matrix for mapping of Nutrient availability map

	pH	**Phosphorus**	**Organic Carbon**	**Nitrogen**	**Potassium**	**Electrical conductivity**
pH	1	9	5	9	9	3
Phosphorus	0.11	1	0.2	0.33	0.33	0.14
Organic Carbon	0.2	5	1	5	5	0.2
Nitrogen	0.11	3	0.2	1	3	0.14
Potassium	0.11	3	0.2	0.33	1	0.14
Electrical Conductivity	0.33	7	5	7	7	1

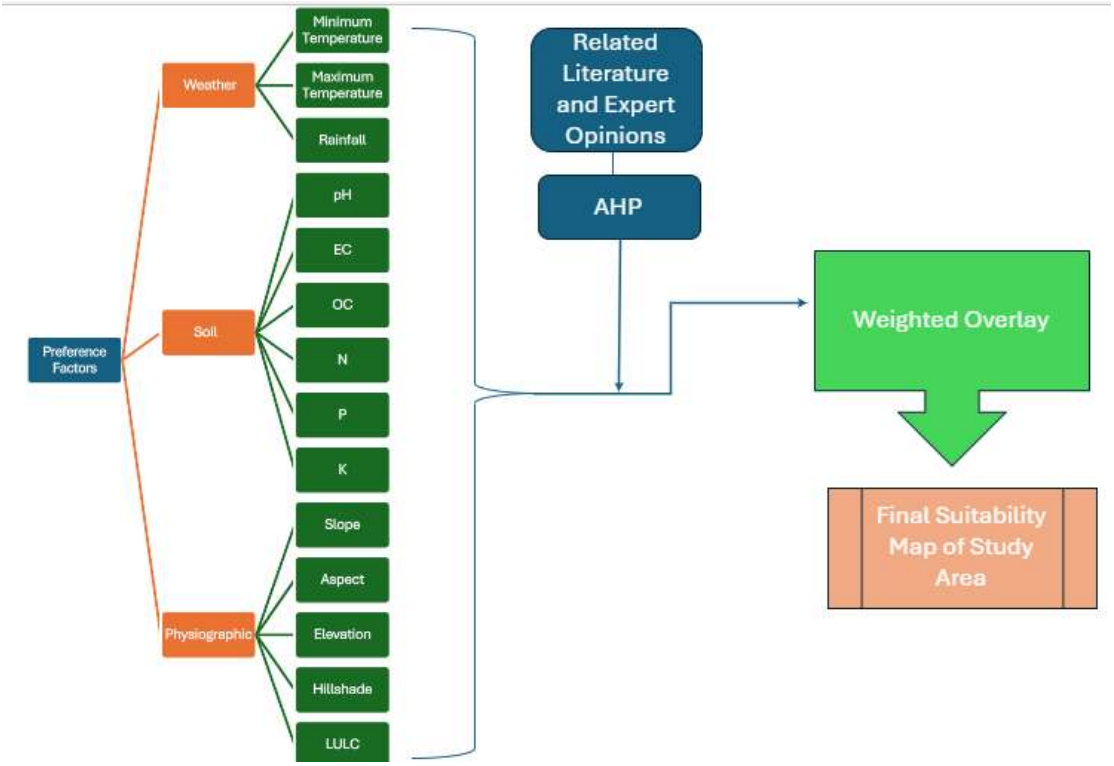

Fig 2. Stepwise illustration of the land suitability methodology

RESULTS AND DISCUSSION

The suitability of sites for major fruit crops (Mango, Guava, Litchi, Citrus and Pomegranate) in the five developmental blocks viz. Amb, Una, Haroli, Gagret and Bangana of the Una district of Himachal Pradesh were analyzed. The soil, weather parameters were analyzed along with the farmer perception data. LULC mapping along with the thematic maps of soil and weather was done through interpolation.

Natural Resource Mapping

A. Physiographic Mapping

Slope Map

A slope map is a topographic map that shows changes in elevation such as incline or decline providing information about the steepness or gentleness of the terrain at specific locations. The slope map was reclassified according to the frost occurrence in relation to the slope degrees. Two classes viz. Not suitable (0˚-25˚) and suitable (25.1˚-53˚) were categorized. The highest degree of slope was taken as frost free whereas low-lying basins were found to be majorly impacted by the frost [18]. Frost tolerant crops (Citrus, Pomegranate) were classified suitable for the low slopes, whereas the frost-susceptible and frost tolerant crops (Mango, Litchi, Guava, Citrus and Pomegranate) were classified as suitable for the high slopes. Reclassified slope map is shown in Figure 3.

Aspect Map

Aspect values indicate the directions the physical slopes face.The aspect map was reclassified for the fruit crop production into six categories according to the fruit suitability to the slope. Reclassified aspect map is shown in Figure 4.

Digital Elevation Map

In District Una, the elevation ranged from 273-1092 meters above mean sea level. The Elevation range 273-1092 m was deemed as suitable for major fruit crop production. The Figure 4.6 shows the reclassified elevation map. The elevation range of Una is suitable for the major fruit crops (Mango, Litchi, Guava, Pomegranate and Citrus) considered under this study. Reclassified elevation map is shown in Figure 5.

Hillshade Map

The hill shade map was reclassified into two classes viz., low to moderate (0-90) and moderate to high (90-180). The low to moderate class was classified as Not suitable whereas the moderate to high class was classified as suitable. Reclassified hill shade map is shown in Figure 6.

B. Thematic maps of Weather properties

Maximum Temperature

The range of average annual maximum temperature was found to be 29.63˚-30.24˚C. The range of maximum temperature was divided into two intervals viz. 29.63˚-29.93˚C and 29.93˚-30.24˚C of majority of area was under the class 29.63˚-29.93˚C as compared to the class 29.93˚-30.24˚C. The maximum temperature map of study area is shown in Figure 7.

Minimum Temperature
The average range of minimum temperature was found to be 6.20˚C-9.52˚C. The range was divided into two intervals. The Interval 6.20˚-7.86˚C had more percentage of area under it. The minimum temperature map was reclassified according to frost relation with temperature. The classes were divided into not suitable and suitable where 6.20˚C-8.00˚C were classified as not suitable because of frost occurrence below 8.00˚ C [19] and 8.00˚C-9.52˚C was classified as suitable for fruit crop production. The suitability map of the minimum temperature of study area is shown in Figure 8.

Rainfall
The range of annual rainfall was from 86.39-107.70 mm. The classes of the rainfall were divided in three equal intervals. The rainfall map of study area is shown in Figure 9.

C. Thematic maps of soil chemical properties
Soil pH
The range of the soil pH was found to be 6.4-7.8. The pH of Una district was found to be mostly in the range of 7.1-7.8 which was slightly alkaline. The soil pH range was found to be in accordance with the findings of [20] in lower Himalayas of Himachal Pradesh.
The thematic maps of the soil pH were reclassified according to the optimum pH requirement of the fruit crops (Mango, Guava, Pomegranate, Litchi, Citrus). Optimum pH for Mango (5.5-7.5) [1] Guava (5.5-7.5) [21], Litchi (5-7), Pomegranate (6.5-7) and Citrus (5.5-6) taken respectively [22]. The reclassified soil pH map is shown in Figure 10.

Electrical Conductivity
The soil EC ranged from 0.10-0.22 dS/m with a mean range of 0.15 dS/m.The findings were in conformity with [23] found the EC range to be 0.094-0.138 ds/m in the Shiwalik hills of Himachal Pradesh. The soil EC was in safe range for all the crops hence deemed suitable for the fruit crops studied. The reclassified soil EC map is shown in Figure 11.

Soil Organic Carbon
The range of the soil organic carbon was from 0.51% -1.51 % with a mean of 1.02%. The organic carbon range was mostly in the medium range. The reclassified soil OC map is shown in Figure 12.

Soil Nitrogen
The range of soil nitrogen was from 188.16-388.86 (kg/ha). The thematic maps of the soil nitrogen was reclassified according to the optimum nitrogen requirement of the fruit crops (Mango, Guava, Pomegranate, Litchi, Citrus). Optimum nitrogen for Mango and Guava (100 kg/ha and 80 kg/ha respectively), Litchi (185kg/ha), Pomegranate (240 kg/ha) and Citrus (160kg/ha.) taken respectively [22]. The reclassified soil nitrogen map is shown in Figure 13.

Soil Potassium
The range of soil potassium was from 101.02-315.45 (kg/ha). [23] studied the soil fertility status in vegetable growing soils of outer Himalayan region and the mean value of potassium was 173 kg/ha which was in accordance with the findings obtained.The thematic map of the soil potassium was reclassified according to the optimum potassium requirement of the fruit crops (Mango, Guava, Pomegranate, Litchi, Citrus). Optimum potassium for Mango and Guava (100 kg/ha and 80 kg/ha respectively.), Litchi (73 kg/ha), Pomegranate (80 kg/ha) and Citrus (30 kg/ha.) taken respectively [22]. The reclassified soil potassium map is shown in Figure 14.

Soil Phosphorus Map
The range of soil phosphorus was from 15.66-61.34 (kg/ha). The thematic map of the soil phosphorus was reclassified according to the optimum phosphorus requirement of the fruit crops (Mango, Guava, Pomegranate, Litchi, Citrus). Optimum phosphorus for Mango and Guava (50 kg/ha and 83 kg/ha respectively.), Litchi (73 kg/ha), Pomegranate (80 kg/ha) and Citrus (60 kg/ha.) taken respectively [22]. The reclassified soil phosphorus map is shown in Figure 15.

Nutrient Availability Map
The nutrient availability map was created with the Analytical Hierarchy Process (AHP) by composition of pairwise comparison matrix considering various soil chemical properties studied viz. pH, Electrical Conductivity (EC), Organic Carbon (OC), Nitrogen (N), Phosphorus (P), Potassium (K). The nutrient availability map was classified into three different equal intervals viz. Not suitable, Moderately suitable, Highly suitable. The nutrient availability map of district Una is shown in Figure 16. The criteria weights computed from pairwise comparison matrix are shown in Table 4.

Table 4. Criteria weights computed from the pairwise comparison matrix

Soil Parameter	Weightage
pH	45.87
Electrical Conductivity (EC)	29.01
Organic Carbon (OC)	13.16
Nitrogen (N)	5.49
Phosphorus (P)	2.64

Potassium (k)	3.81

[2] generated nutrient availability map for agroforestry suitability analysis according to the similar criteria of Analytical Hierarchy Process.

Results of Survey Questionnaire

A survey questionnaire was conducted with a sample number of 75 in five blocks (Bangana, Haroli, Amb, Una, Gagret) of Una district, H.P. among the fruit growers and the non-fruit growers about the facilities and the problem faced. Among the fruit growers,16% found fruit production not profitable whereas 84% found it profitable. 59% had institutional support and 41% had no institutional support. 45% had access to packaging facilities. 55% had no access to packaging facilities. 25% sold their produce directly without any inter mediator. 75% sold their produce through APMC. 21% had crop insurance.79% had no crop insurance. 46% had training acquired. 54% had no training acquired. For non fruit growers surveyed 82% of the farmers wanted to adopt the fruit growing whereas 18% of them did not want to adopt the fruit production.

Mapping of Land Use Land Cover (LULC)

The Land Use Land Cover (LULC) of the study area was prepared using the Sentinel 2A/2B data. The Land Use Land Cover was classified into six classes viz. Agriculture, Barren Land, Sediments, Settlements, Forests, Water Bodies. Supervised classification was used for developing the spectral signatures aiding in classifying the LULC. [24] employed the similar technique of supervised classification for developing the spectral signature of already identified categories or classes. The software identifies the color of the pixels selected from the selected categories for classifying the classes.
The Land Use Land cover map was reclassified into three categories viz. 1) Not suitable 2) Highly suitable 3) Moderately suitable. The Forest cover, Built-up, Sediments, Water body classes were categorized as not suitable areas for the planting of fruit crops whereas the agriculture class was categorized as highly suitable and other land category was categorized as moderately suitable. The reclassified land use land cover map of district Una is shown in Figure 17. Table 5 shows the area under different categories of reclassified land use land cover map.

Table 5. Area under different categories of reclassified map

Reclassified Category	Area percentage (%)	Area (sq.km.)
Not suitable	41.14	634.25
Moderately suitable	29.14	449.21
Highly suitable	29.70	457.88

Mapping of Final Suitability Map

The final suitability map was mapped by executing the preference matrices created in the Analytical Hierarchy Process (AHP) [25]. Table 6 shows the weights computed for different parameters from the comparison matrix.

Table 6. Weights computed for different parameters from the comparison matrix

Parameters	Weights
Maximum temperature	8.99
Minimum temperature	12.46
Slope	25.38
Aspect	34.61
Elevation	6.31
Land use land cover	1.66
Hillshade	2.62
Rainfall	3.13
Nutrient availability parameters	4.80

The Consistency Ratio (CR) of the preference matrix created was 0.0906 which was appropriate according to the fact that Consistency Ratio (CR) should be less than 0.1.

Final Suitability map of the Potential Areas

The final suitability map of the potential areas was mapped by masking the unsuitable classes viz. Forest cover, Settlements, Water bodies and Sediments. The final map consisting of Agriculture and barren land classes was divided into three suitability classes: Highly suitable, Moderately suitable, Not suitable. Table 7 shows the area under agriculture class which is suitable for fruit crop production. Similarly, Table 8 shows the area under barren land class which is suitable for fruit crop production. Figure 18 represents the final suitability map of the study area.

Table 7. Area under Agriculture Class

Class	Area (sq.km.)

Highly suitable	121.66
Moderately suitable	218.74
Not suitable	110.10

Table 8. Area under Barren Land

Class	Area (sq.km.)
Highly suitable	112.99
Moderately suitable	222.29
Not suitable	106.29

Barren Land class had maximum area under Moderately suitable class (222.29 sq.km.) followed by Highly suitable (112.99 sq.km.) and Not suitable (106.29 sq.km.) had the least area. [26] employed the similar technique of AHP and GIS tools for land suitability analysis of the Cihanbeyli county (Turkey).

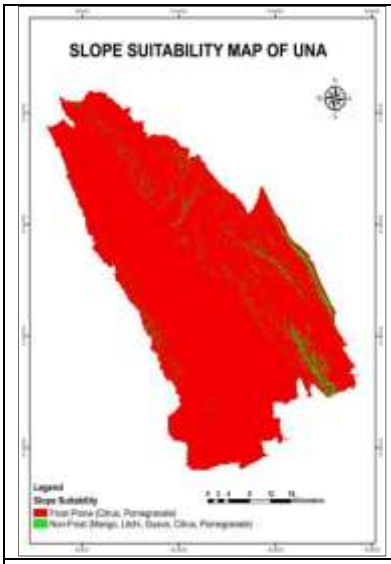

Fig.3 Slope suitability map

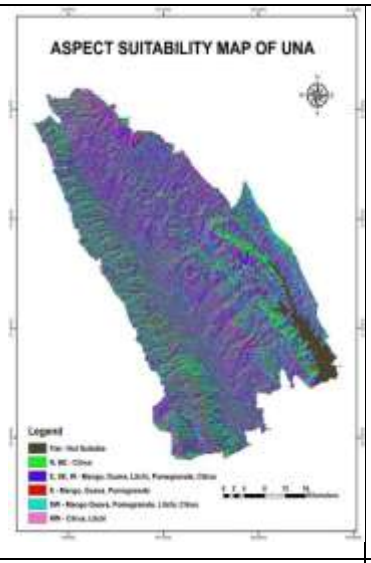

Fig. 4 Aspect suitability map

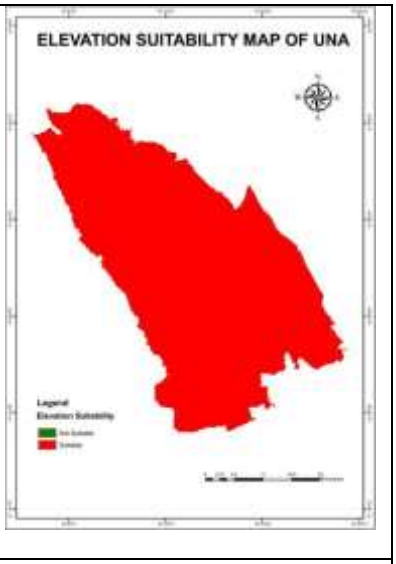

Fig. 5 Elevation suitability map

Fig. 6 Hillshade suitability map

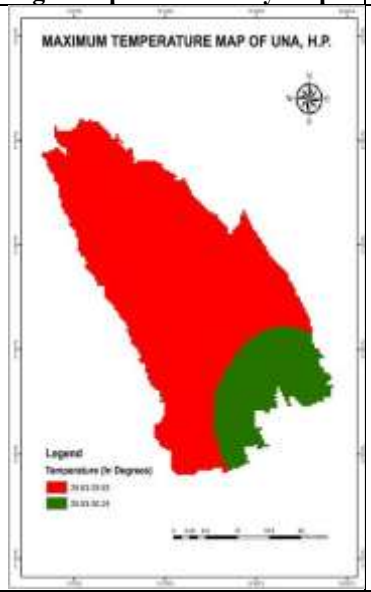

Fig. 7 Maximum Temperature Map

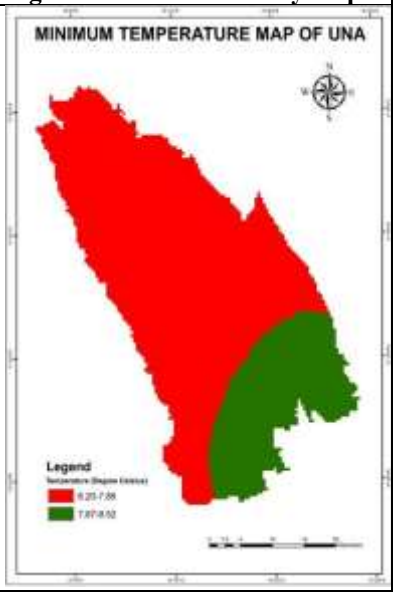

Fig. 8 Minimum Temperature Map

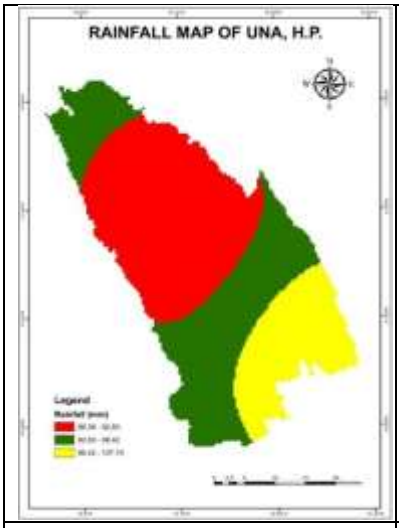

Fig. 9 Rainfall Map

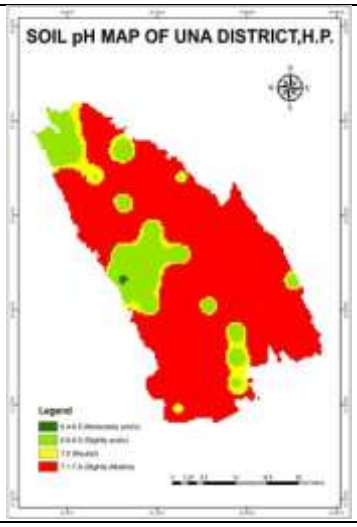

Fig. 10 Soil pH Map

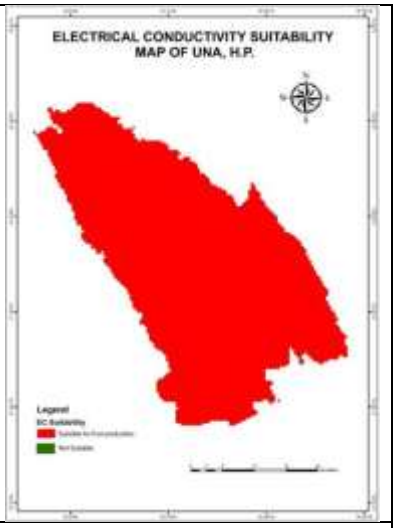

Fig. 11 Soil EC Map

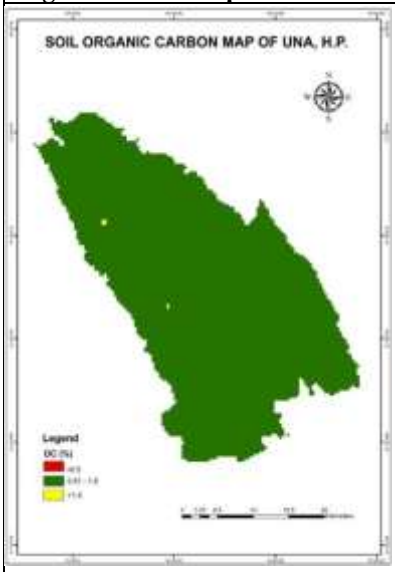

Fig. 12 Soil OC Map

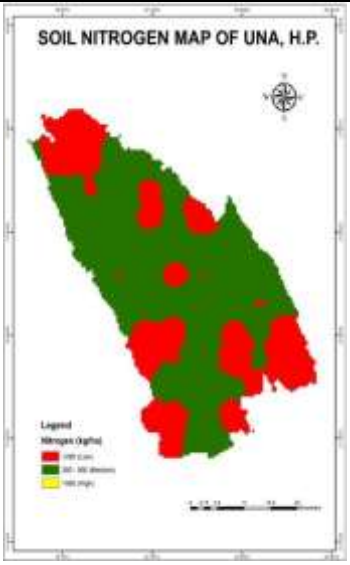

Fig. 13 Soil Nitrogen Map

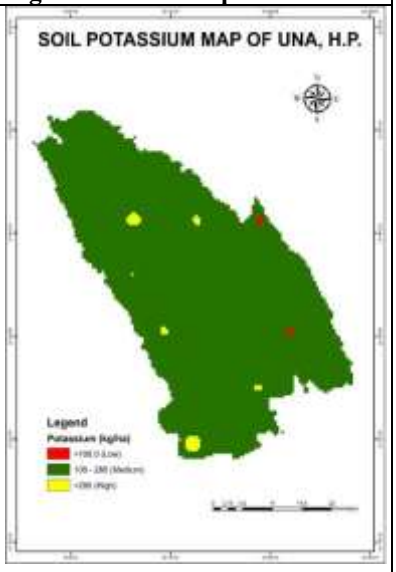

Fig. 14 Soil Potassium Map

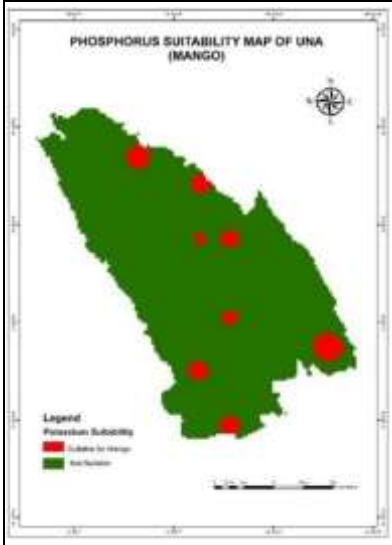

Fig. 15 Soil Phosphorus Map

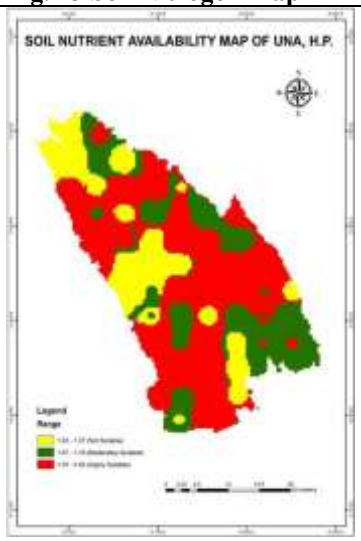

Fig. 16 Soil Nutrient Availability Map

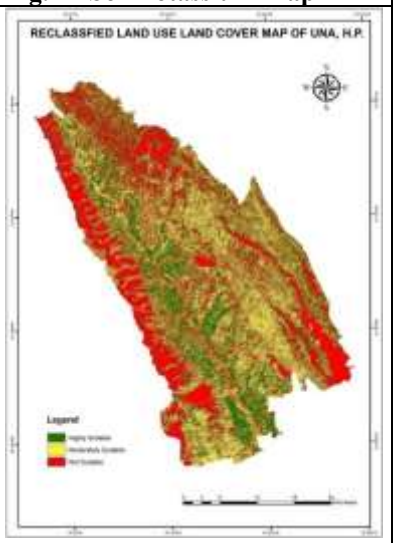

Fig. 17 Land Use Land Cover Map

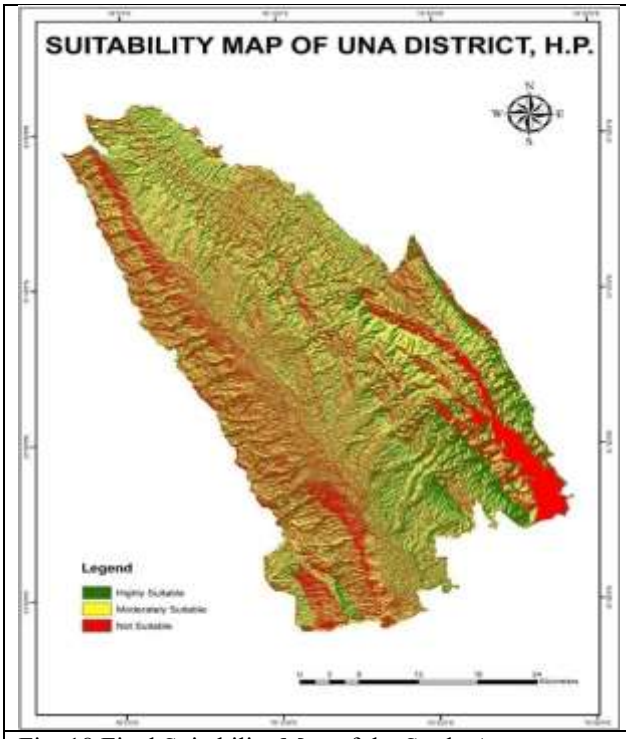

Fig. 18 Final Suitability Map of the Study Area

CONCLUSION

A conclusion can be made from the available final suitability map that the district Una offers a good suitability for the major fruit crops studied. The available barren land also provides an effective area for fruit production. The nutrient availability map shows that major chunk of portion of the study area has high nutrient availability. The Land use Land cover map generated shows that there is considerable area under agriculture and barren land which can offer an increase in the fruit production area. Weather data of the area is in favourable range for fruit production. The questionnaire reveals that the majority of farmers are willing to adopt fruit production but the majority of them face various problems and supporting infrastructural facilities are scarce in the proximity which hinders the farmers from producing fruit. To conclude, results of suitability map indicate potentialities and further policy support to boost fruit production in Una district.

Author Contributions:

Shahid Khan and Aashima Sharma conducted the research and prepared the first draft of manuscript. Dr. Vikas Kumar Sharma and Dr. Vipasha Sharma proposed and planned the research. Dr. Yashasvi Thakur prepared the final draft of the manuscript. All the authors conducted the final proof reading.

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