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Geospatial mapping at block scale for assessment of fruit crop diversity

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ABSTRACT

A geospatial-based study was conducted in the Bijhari block of district Hamirpur, Himachal Pradesh to analyze the fruit crop diversity of the study area. This block is situated in the hilly terrain which makes it difficult for such a study to be carried out in this area, the main challenges being the estimation of area under various fruit crops and the LULC mapping. The survey of the study area was conducted to prepare the fruit crop diversity map of the study area. The ground truth data and the soil samples were collected from the survey sites. Sentinel satellite data obtained from the European Space Agency were used to generate the NDVI and LULC maps. Thematic maps of soil pH, soil EC and soil OC were prepared by the IDW method. All the maps were prepared using the ESRI ArcMap 10.6.1 software. The fruit crop diversity map revealed that mango was the main fruit crop grown in the Bijhari block. The NDVI map showed that the maximum area was under the dense vegetation class in the selected block. Results of LULC mapping have shown that the tree cover occupies the maximum area in the Bijhari block. The pH of most of the soil samples was slightly acidic. Soil EC was found in safe ranges for the study area. Soil OC of most soil samples was in the medium and high ranges for the Bijhari block.

Keywords: *Geospatial, Bijhari, Fruit crop diversity, NDVI, LULC, Soil pH, EC, OC, ArcMAP.*

INTRODUCTION

The Himachal Himalayas span from the Shiwalik hills in the south to the Great Himalayan range, encompassing a portion of the Trans-Himalaya to the north. Geographically, Himachal Pradesh extends between Latitudes 30°22'40'' N and 33°12'40'' N, and Longitudes 75°45'55''E and 79°04'20''E, with altitudes ranging from 350 meters (in low valleys) to 6,975 meters (in snow-covered mountains) above mean sea level [1].

Situated exclusively within the Western Himalayas, Himachal Pradesh exhibits a wide array of relief features and varying land slopes [2]. There are twelve districts in the state. District Hamirpur of Himachal Pradesh is situated between 31°25' N to 31°52' N Latitudes and 76°18' E to 76°44' E Longitudes. The tract of the district is covered by the Shiwalik range and is hilly. The elevation of the district varies from 400 m to 1200 m above mean sea level. The total area of the district is 1,118 sq.km. that forms 2.01 percent of the total area of the state. The district Hamirpur of Himachal Pradesh consists of six development blocks, *viz*., Hamirpur, Sujanpur, Nadaun, Bhoranj, Bijhari and Bamson [3].

Geospatial technology integrates four essential components: Remote Sensing (RS), Geographic Information Systems (GIS), Global Positioning Systems (GPS) and Information Technology (IT) [4]. Utilizing geospatial technology, particularly Geographic Information Systems (GIS), for orchard delineation and spatial analysis can be a potential tool for facilitating the advancement of fruit cultivation, particularly in countries like India which is characterized by vast agro-ecological diversity.

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With a robust database, GIS emerges as a pivotal tool for analytical insights and informed decision-making. It stands out as one of the foremost techniques extensively employed for mapping fruit trees [5]. The utilization of GIS expedites the data acquisition and analysis process significantly compared to the traditional methods. Geospatial technology, including GIS, serves as a valuable tool for mapping fruit trees and finds applications across various domains such as crop inventory, monitoring crop conditions and production forecasts, assessing fruit quality, determining leaf area index, evaluating crown cover, monitoring horticultural crop growth and health, conducting drought and flood damage assessments, as well as managing and monitoring irrigated soils [6,7]. Various soil attributes, climatic factors and land-use classifications are the primary determinants influencing the growth and productivity of fruit crops [8]. Soil attributes such as pH levels, nutrient content, and electrical conductivity play crucial roles in fruit production, while climatic elements including temperature, precipitation and frost occurrences also influence crop growth. It is imperative to incorporate these physical parameters into a geospatial database, aligning them with spatial-based yield data for fruit and nut crops, to construct an effective GIS model [9]. RS and GIS have demonstrated significant utility in detecting NDVI (Normalized Difference Vegetation Index) and Land Use/Land Cover (LULC) patterns, as well as tracking their temporal changes [10,11]. Physical planning maps serve a dual purpose, facilitating the implementation of land use plans and conveying regulations regarding permissible land activities within specific geographical areas or parcels. The climatic facets of regional geography encompass the interplay between natural and cultural elements of a region and its climate. However, local climatic conditions, influenced by topography, often occur at a scale too fine to be depicted on regional maps[12].

Therefore, the study aimed to analyze the fruit crop diversity in the Bijhari block of the district of Hamirpur, Himachal Pradesh.

The total area under fruit crops was calculated using geospatial tools. The NDVI and LULC of the study area were prepared along with the thematic maps of soil pH, soil EC and soil OC.

MATERIALS AND METHODS

Study Area

The study was conducted in the Bijhari block of the district of Hamirpur, Himachal Pradesh. The Bijhari block is located between 31^{0}25'34'' N to 31^{0}38'21'' N Latitude and 76^{0}23'22'' E to 76^{0}36'10'' E Longitude. The altitude of the block ranges from 534 m to 1033 m above mean sea level. The total area of Bijhari block is estimated to be 288.38 sq.km. The location map of the study area is shown in Figure 1.

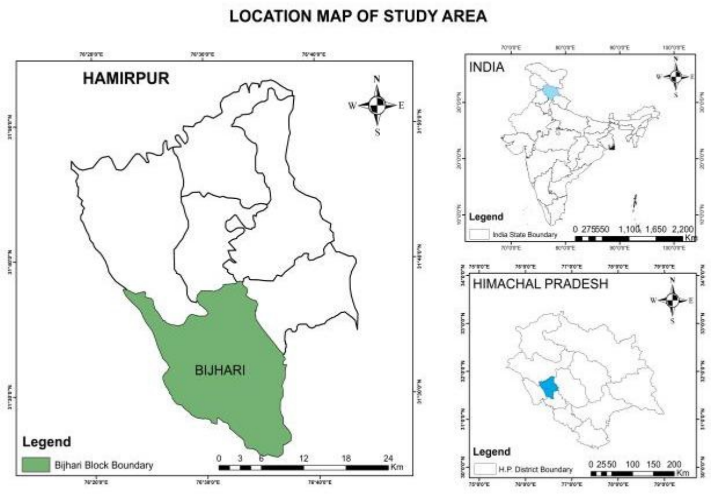

Figure 1. Location map of the study area

Data Used

Different types of data such as spatial and non-spatial data have been used in this study.

Ancillary/Collateral Data: The important collateral data used included the administrative boundary of the block, location of settlements, drainage/rivers, *etc*. and the area and production statistics of different fruits in the area.

Ground Truth/Sample Data: Data were collected to acquire the location of the orchards. The data collected included the geographical coordinates of the location and soil samples from the orchards. The locations were recorded with the help of maps and Global Positioning System (GPS). The surface soils of the fruit orchards visited during the survey were sampled randomly to a depth of 0-15 cm in a triangular shape with the help of a khurpi.

Satellite Data: The Sentinel-2 data were downloaded from the ESA (European Space Agency) Copernicus open access hub. The four bands of 10 m spatial resolution, *viz*., blue, green, red and near infrared (NIR) were used to generate the NDVI and LULC map of the study area. For the present assessment of land use and land cover and for the generation of NDVI the Sentinel-2 data of 2021 were utilized for mapping.

METHODOLOGY

A preliminary survey of the major fruit orchards of Bijhari block of Hamirpur district was conducted to obtain information about the area under different fruit crops, the topography of the area, soil analysis of the orchards and location. The data of major fruit orchards were collected from the Department of Horticulture, Hamirpur, HP. The location of the orchards was recorded with Global Positioning System (GPS), soil samples from the orchards were collected from the top layer (0-15 cm) of the orchard and the topography of the orchards was observed visually.

Analysis of area under fruit crops: The GPS location of the orchards visited during the survey was checked in the Google Earth Explorer. The area under different fruit crops was traced by drawing the polygons of the boundary of the orchard on satellite data in ArcMap 10.6.1 software.

Normalized Difference Vegetation Index (NDVI) Calculation: The NDVI of the study area was generated from the reflectance of images for comparing and editing classification results. Vegetation has a distinctive spectral signature that is distinguished by low reflectivity in the infrared (IR) spectrum. Higher NDVI reflects a higher amount of green vegetation on the ground. In general, the NDVI of non-vegetation areas was generally lower than that of vegetation classes. The Sentinel-2 (2B-2A) satellite data were used to generate NDVI maps of the study area. The map was reclassified using the spatial analyst tool using the reclassify option into five classes.

Using the satellite data and ground truth information, the exact value of the NDVI for the threshold was generated. NDVI calculation involves the reflectance of the electromagnetic spectrum which is sensitive to vegetation cover, biomass, crop condition and density in red and near-infrared bands. The NDVI of imagery was calculated using the mathematical formula given below [13]:

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{Red}}{\mathrm{NIR} + \mathrm{Red}}$$

The formula above indicates that the values of NDVI are unitless with ranges of upper limit +1 and lower limit of -1.

Land Use Land Cover (LULC) Classification: The Sentinel-2 (2B-2A) data were preprocessed in ArcMap 10.6.1. Based on the preliminary survey and ground truth data, the satellite image of the study area was classified using a maximum likelihood classifier under a supervised classification method. Supervised classification uses the spectral signatures obtained from training samples to classify an image. The three bands of Sentinel-2 data were used to generate the LULC classes, band 8 (NIR), band 4 (Red) and band 3 (Green). To represent each class a number of training areas were selected. Using ground truth data, five classes of LULC were generated using this method for the study area. The five classes were tree cover, settlement, water bodies, agricultural land and other land. The accuracy assessment was done by selecting 100 random points in the study area and confirming the results by ground truth data. The methodology chart for the preparation of NDVI and LULC is given in Figure 2.

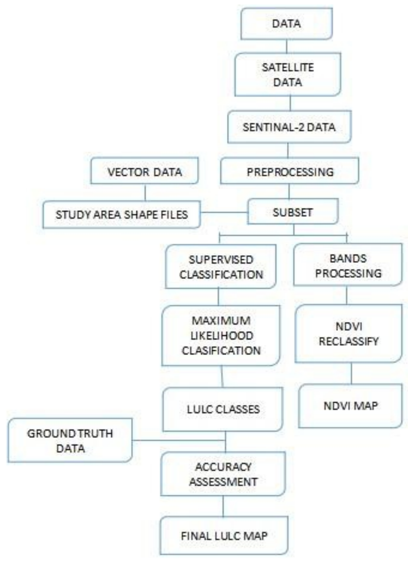

Figure 2. Methodology chart for the preparation of NDVI and LULC

Thematic Maps of Soil Chemical Properties: The surface soil of the fruit orchards visited during the survey of Bijhari block was sampled randomly to a depth of 0-15 cm in a triangular shape with the help of a khurpi. The organic matter and debris present on the top of the soil were removed manually. The soil samples were mixed thoroughly and a kilogram of composite sample was drawn from each site.

Soil chemical properties, *viz.*, soil pH, soil EC and soil OC were estimated in the laboratory. The electrometric method was used to determine the pH and Electrical Conductivity (EC) of the soil samples [14]. Organic matter of the soils was estimated by the chromic acid wet digestion method given by [15]. Thematic maps of these soil chemical properties were prepared using the IDW (Inverse Distance Weighted) Spatial Interpolation technique in ArcMap 10.6.1 software. The methodology chart for the preparation of thematic maps of soil chemical properties is given in Figure 3.

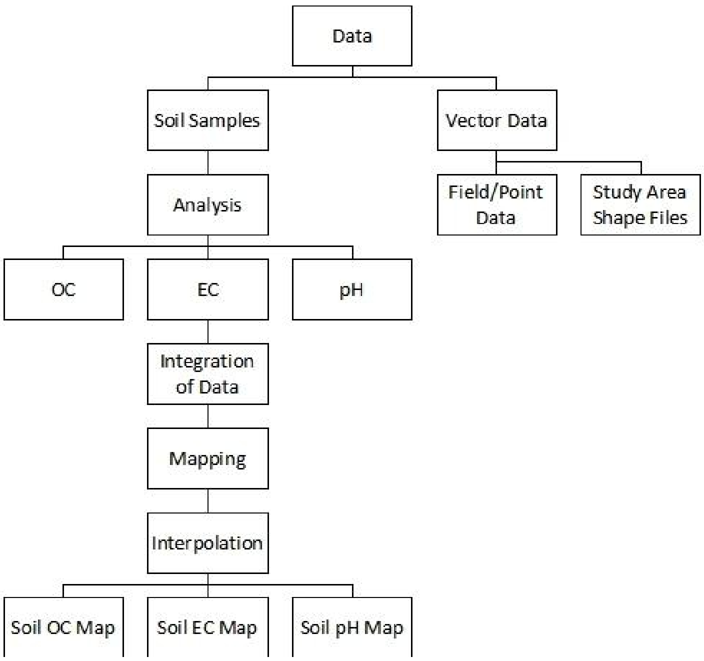

Figure 3. Methodology chart for preparation of thematic maps of soil chemical properties

RESULTS AND DISCUSSION

Fruit Crop Diversity

The important fruit crops grown in Bijhari block include mango, citrus and pomegranate. The thematic map of fruit crop diversity of Bijhari was prepared by placing point locations in the study area boundaries. The boundaries of individual orchards of different fruit crops were traced in the ArcGIS software on the satellite images of the study area. This aids in determining the area occupied by different fruit crops within a specific orchard, thereby contributing to the overall assessment of fruit crop distribution within the block. The fruit crop diversity map of Bijhari is shown in Figure 4. The total area under different fruit crops in Bijhari is given in Table 1.

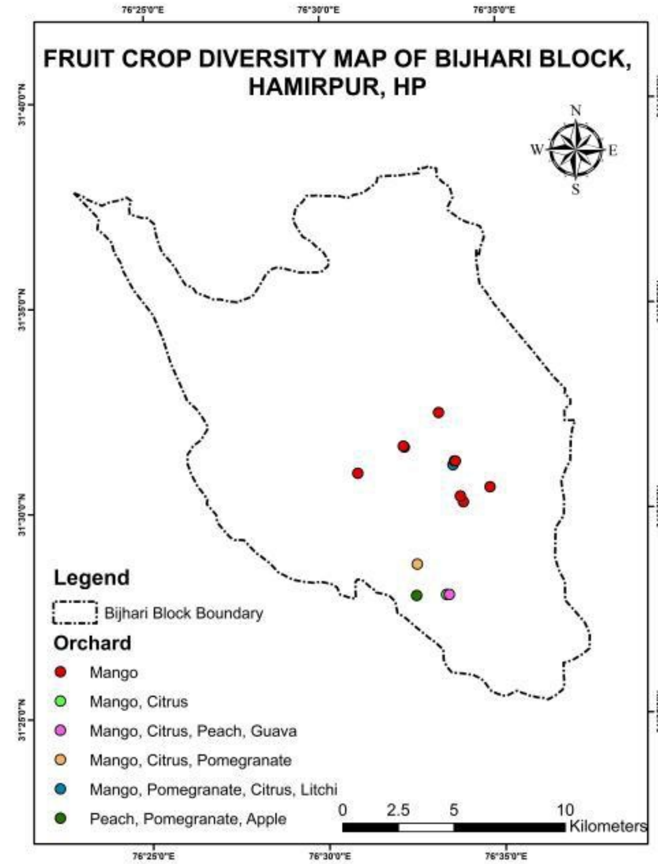

Figure 4. Fruit crop diversity map of Bijhari block

Table 1. Total area under different fruit crops in orchards surveyed calculated using geospatial tools

Fruit Crop	Area (sq.km.)	Area (%)
Mango	135583.57	70.46
Citrus	31483.74	16.36
Pomegranate	10292.53	5.35
Litchi	9614.11	4.99
Peach	3053.55	1.59
Guava	1505.62	0.78
Apple	902.77	0.47
Total	192432.89	100

Normalized Difference Vegetation Index (NDVI) generation: The NDVI ranges are different for different classes of features on land. [16] suggested that NDVI is an useful method to detect the production of green vegetation. The NDVI of Bijhari ranged between -0.39 to +0.91. The NDVI map of Bijhari is shown in figure 5. The area under different classes of NDVI is shown in table 2.

Table 2. Area under different classes of Normalized Difference Vegetation Index (NDVI) of Bijhari block

S.No.	Class	Vegetation Indices	Area (sq.km.)
1.	Non Vegetation Areas	< 0.1	1.66
2.	Low Vegetation Areas	0.1-0.3	8.69
3.	Sparse Vegetation Areas	0.3-0.5	27.74
4.	Dense Vegetation Areas	0.5-0.7	143.36
5.	Very Dense Vegetation Areas	0.7-1.0	106.93
Total			288.38

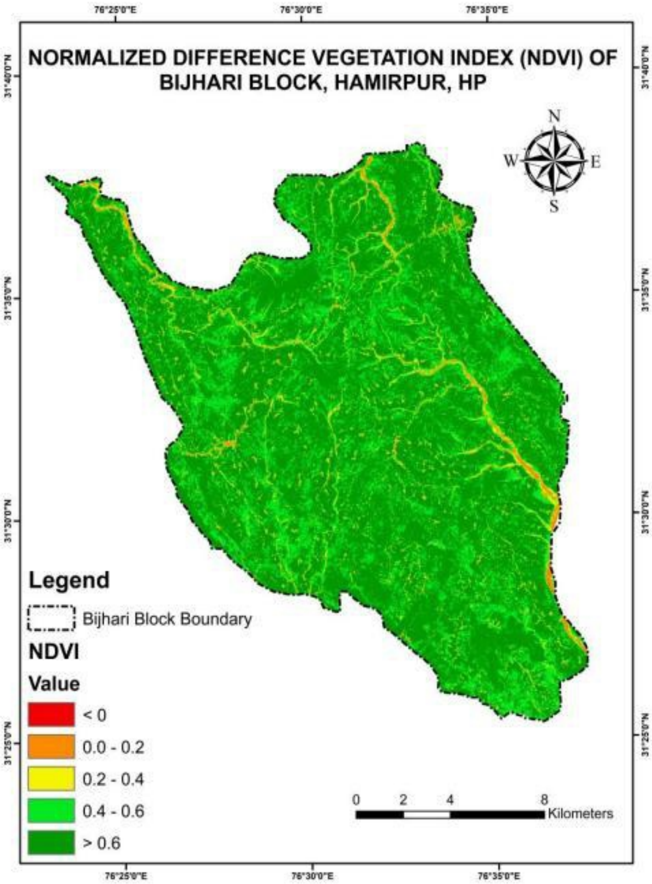

Figure 5. NDVI of Bijhari block

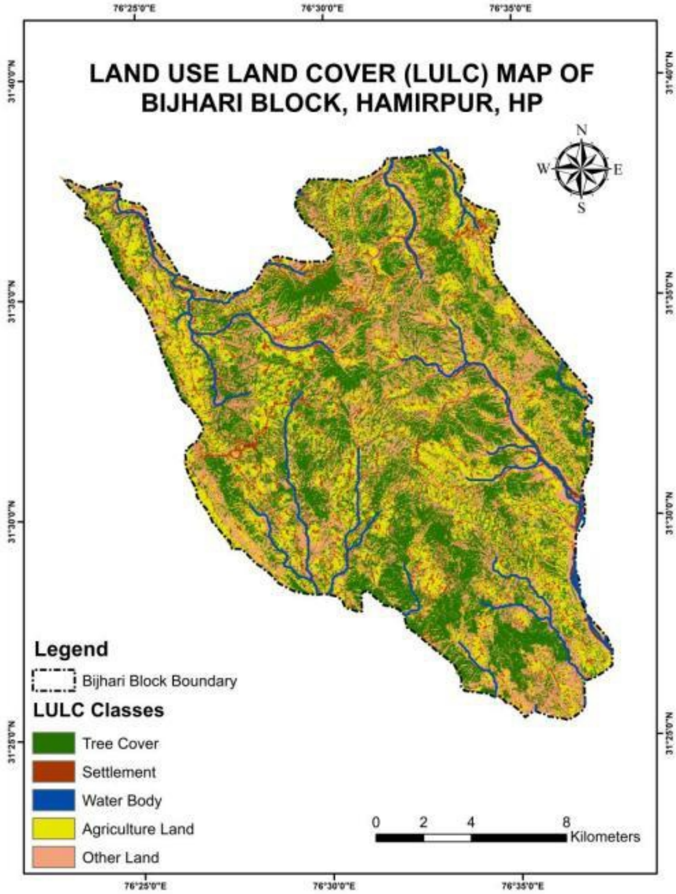

Figure 6. LULC map of Bijhari block

The maximum area of the Bijhari block was recorded under dense vegetation class i.e. 143.36 sq. km., while the non-vegetation class covered a minimum area of 1.66 sq.km. The area under the very dense class was 106.93 sq.km., the sparse vegetation class was 27.74 sq.km. and the low vegetation class was 8.69 sq.km. According to [17], NDVI is a relevant index for areas of medium to high vegetation density, since it is less susceptible to the soil and to the effects of the atmosphere. The index values range from −1 to +1 and is based on the high reflection of the healthy plants in the wavelengths in the infrared band and its low reflection in the presence of the red band of the electromagnetic spectrum [18], therefore, healthy forest cover usually has higher NDVI values.

LULC Map: The Land Use Land Cover map of the study area was prepared using Sentinel 2 data. [19] stated that LULC prepared from Sentinel-2 data was more accurate as compared to the Landsat data. The LULC was categorized into five classes *viz*., tree cover, settlement, water body, agriculture land and other land. The LULC map of Bijhari block is shown in Figure 6 and the area under various classes of LULC is shown in Table 3.

Table 3. Area under different classes of Land Use Land Cover (LULC) of Bijhari block

Land Use Category	Area Percentage(%)	Area (sq.km.)
Tree Cover	35.25	101.66
Settlement	10.21	29.43
Water Body	0.73	2.11
Agriculture Land	27.49	79.28
Other Land	26.32	75.90
Total	100	288.38

The maximum area in the block was under tree cover, *i.e*., 35.25% (101.66 sq.km.) and the minimum area was under water body class, *i.e*., 0.73% (2.11 sq.km.). The area under settlement was 29.43 sq.km., the area under agricultural land was 79.28 sq.km. and the area under other lands was 75.90 sq.km.

Thematic Maps of Soil Chemical Properties

Thematic maps of soil chemical properties *viz*., soil pH, soil electrical conductivity and soil organic carbon, were prepared using the spatial interpolation technique. This technique provides us with spatial variation of the desired properties over the whole of the study area.

The soil pH was divided into four classes, *viz*., moderately acidic (5.6-6.5), slightly acidic (6.6-6.9), neutral (7.0) and slightly alkaline (7.1-8.0). The pH of soil samples taken from survey sites ranged between 6.38-7.22 with a mean value of 6.67. The pH of Bijhari was mostly in the slightly acidic class.

The soil EC was divided into two classes *viz*., safe (<0.8 dS/m) and unsafe (>0.8 dS/m). The EC of soil samples taken from survey sites of Bijhari block ranged between 0.025-0.118 dS/m with a mean value of 0.054 dS/m. The EC of was found to be in a safe range, indicating the non-saline nature of the soils.

The soil OC was divided into three classes *viz*., low (< 0.50%), medium (0.50%-1.50%) and high (> 1.50%). The range of OC in soil samples taken from survey sites of Bijhari block was found to be 0.42-2.97% with a mean value of 1.34%. The Organic Carbon (OC) levels were predominantly in the medium range, with some reaching the high range. The thematic maps of soil pH, EC and OC are shown in Figures 7, 8 and 9 respectively.

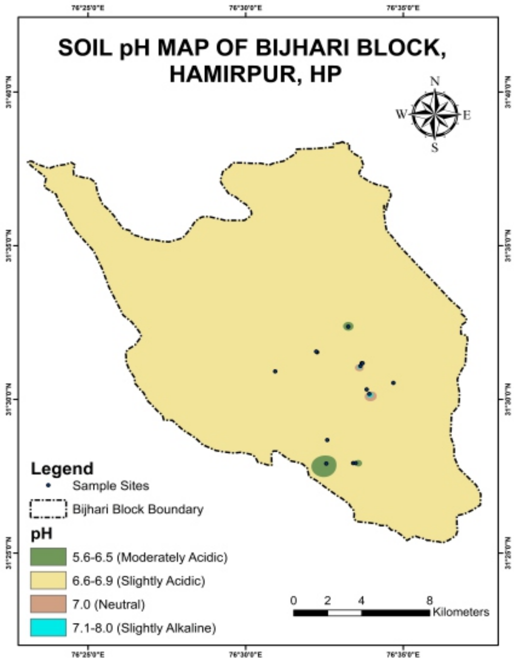

Figure 7. Soil pH map of Bijhari Block

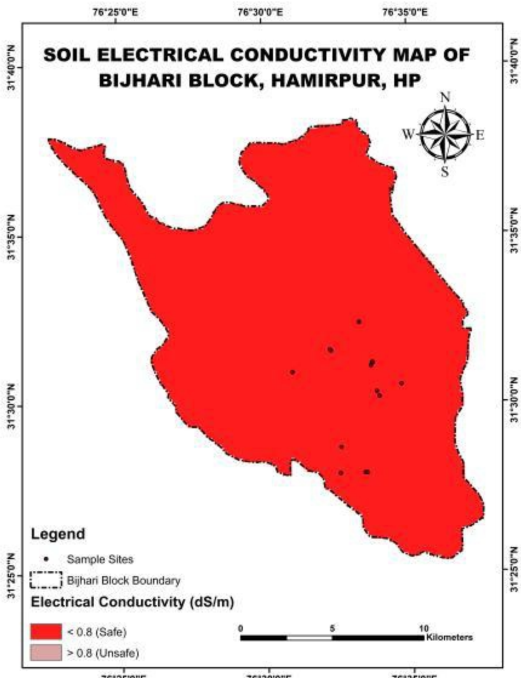

Figure 8. Soil EC map of Bijhari Block

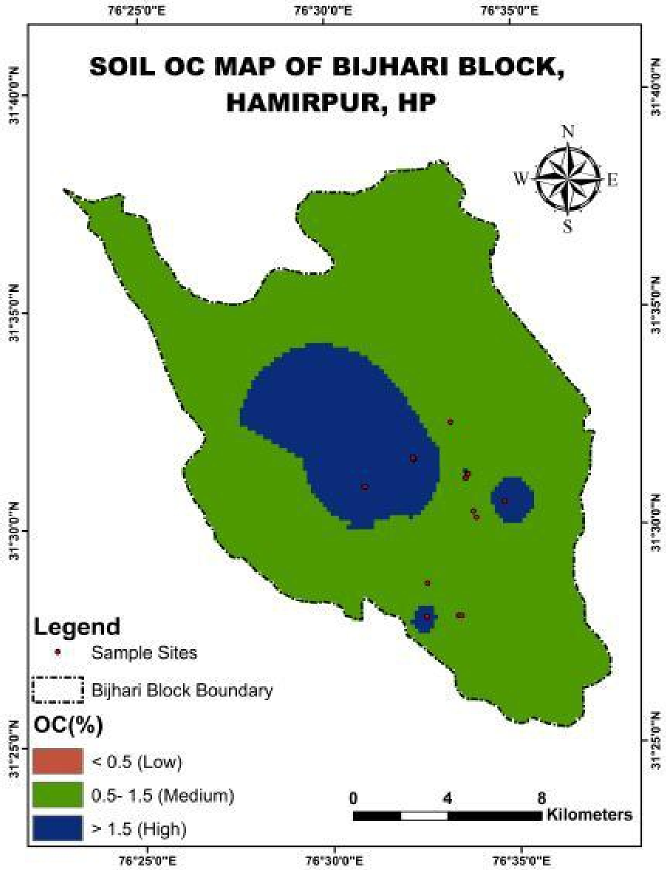

Figure 9. Soil OC map of Bijhari Block

CONCLUSION

The fruit crop diversity map showed a major area under the cultivation of mango and citrus, while a minimal area was found under the cultivation of other fruit crops. Further investigations are necessary to pinpoint potential fruit crops and areas conducive to their cultivation, thereby maximizing profitability for farmers. The NDVI map revealed that the majority of the area was under dense vegetation class the block which happens to be the agricultural land and sparse tree plantations. LULC map of the study area also reveals that there is a substantial amount of land under agriculture and other lands that offer an opportunity to increase the area under fruit crop production after identifying the suitable areas. Thematic maps of soil pH, EC and OC were prepared based on the analysis of the soil samples collected from the survey sites during the survey. However, more detailed information about the soil chemical properties in these areas can be generated by wider and thorough sampling of the areas. Further, this study in future, with a more detailed and thorough evaluation can be utilized for studying the change in area under cultivation of major fruit crops of the area and the suitability of this region of various fruit crops which can therefore aid in bringing more area under fruit cultivation.

Author Contributions: Aashima Sharma conducted the research and prepared the first draft of the manuscript. Vikas Kumar Sharma proposed and planned the research. Yashasvi Thakur prepared the final draft of the manuscript. All the authors conducted the final proofreading.

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Conflicts of Interest: The authors declare no conflict of interest.

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