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ASSESSMENT OF FRUIT CROP DIVERSITY IN RELATION TO ENVIRONMENTAL DYNAMICS IN LOW HILLS OF HIMACHAL PRADESH

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ABSTRACT
The climatic conditions of Himachal Pradesh are favorable for cultivation of various fruit crops. A thorough study was conducted in the Nadaun block of Hamirpur district which majorly falls in the low hills of the state. The study aimed to assess fruit crop diversity, to investigate the impact of meteorological parameters on the yield of predominant fruit crops, to generate the Normalized Difference Vegetation Index (NDVI) and Land Use/Land Cover (LULC) maps of the area. It was observed that mango and citrus were the predominant fruit crops being cultivated in the study area. A negative correlation was observed between the fruit production and the rainfall change pattern data whereas no discernible correlations were obtained for minimum and maximum temperatures with the fruit crop production data of the study area for the years 2002-2021. The NDVI of the study area indicated that a significant portion of the Nadaun block had dense vegetation cover, suggesting favorable agricultural conditions. Similarly, LULC mapping revealed that the predominant land use class of Nadaun is agriculture class, highlighting the region's agricultural significance. These findings provide valuable insights into the fruit crop diversity, agricultural dynamics and environmental characteristics of the Nadaun block in Himachal Pradesh, supporting informed decision-making for agricultural management and land use planning.

KEYWORD: Environmental Dynamics, Fruit Crop Diversity, Correlation, LULC, NDVI.

INTRODUCTION
Himachal Pradesh is recognized as one of the most environmentally fragile areas in the Indian Himalayan region, favouring abundant natural resources and biodiversity (Rani and Prasher, 2020). There is a great significance of horticulture sector in mountainous and uneven landscapes. Similar conditions are observed in the state of Himachal Pradesh, where conventional agriculture may not be economically very viable. Given the general favorable climate for temperate and subtropical fruits, there exists substantial untapped potential for horticultural crops in this region (Singh et al., 2017). The state of Himachal Pradesh harbors significant potential for cultivating a diverse array of fruits, ranging from tropical to temperate cultivars. Its climate is conducive for fruit cultivation, with apple and stone fruits thriving in the northern high hills while citrus and mango flourish in the lower hills of the state (Kaur, 2021).
The growth and production of fruit crops are primarily influenced by various soil attributes, climatic factors and land use type (Chuong, 2011). The climatic elements essential for fruit production include temperature, precipitation and frost occurrences. These climate parameters need to be integrated into a geospatial database and correlating them with spatial-based yield data for fruit and nut crops can help to construct a GIS model for development purposes (Rumayor-Rodriguez et al., 1998; Panda et al., 2010). Utilizing geospatial technology for orchard delineation and spatial analysis offers valuable insights for management decisions. Therefore, Remote Sensing (RS) has gained significance for broad-scale monitoring of orchard growth and health (Panda et al., 2010; Singh et al., 2017). Remote Sensing (RS) and Geographic Information Systems (GIS) have been widely acknowledged as indispensable and potent tools for assessing Land Use Land Cover (LULC) alterations across various spatial scales. They have consistently demonstrated their effectiveness in identifying LULC patterns and monitoring their evolution over time (Roy and Roy, 2010; Attri et al., 2015).
Therefore, it becomes essential to use the geospatial database for conducting studies at small scales. Using this a database can therefore be generated for the areas that can further help in future policy plannings and land use planning. The present study was undertaken to analyze the fruit crop diversity of the Nadaun block of district Hamirpur, Himachal Pradesh which lies in the sub-tropical humid region of the state. The correlation of weather parameters viz., maximum temperature, minimum temperature and rainfall was assessed on the major fruit crops grown in the region. The NDVI and LULC maps of the study area were also generated.

MATERIALS AND METHODS

Study Area

The Nadaun block of Hamirpur district is situated between Hamirpur and Kangra towns. It is situated at the foothills of Shivalik ranges on the left bank of river Beas (Figure 1). The total estimated area of Nadaun block is 259.02 sq.km. It is located between 31^{0}35’05’’ N to 31^{0}48’56’’ N Latitude and 76^{0}18’02’’ E to 76^{0}30’25’’ E Longitude. The altitude of the block ranges from 420 m to 908 m above mean sea level.

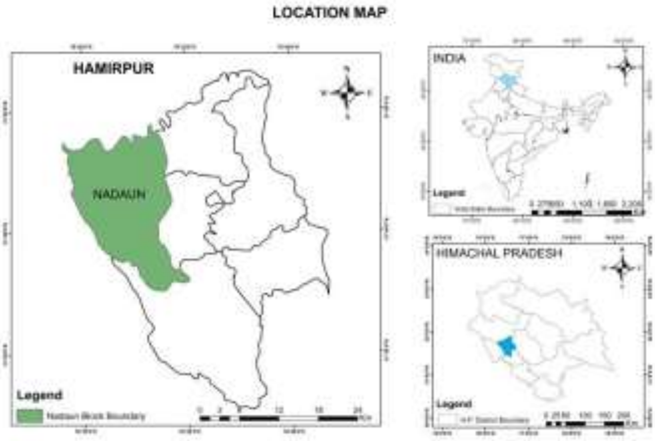

Fig 1. Location Map of Study Area

Data Used

Spatial and non-spatial data both were utilized in this study. Ancillary or collateral data was collected to gather information regarding administrative boundaries of the block, settlement locations and drainage/rivers along with the area and production statistics of different fruits in the area. Ground truth and sample data were collected to identify the location of the orchards. Weather data were sourced from the Climate Data Service Portal of the Indian Meteorological Department, Ministry of Earth Sciences. Gridded data files for rainfall and mean annual temperature, spanning from 2002 to 2021, were obtained from the IMD website. These data covered annual rainfall, mean annual maximum temperature and mean annual minimum temperature for the study area. Crop production data spanning for past 20 years (2002-2021) of various fruit crops such as mango, citrus, plum and others were acquired from the Department of Horticulture, Hamirpur, Himachal Pradesh. Additionally, Sentinel-2 data for October 2021 were downloaded from the ESA (European Space Agency) Copernicus open access hub. Utilization of the four bands with a spatial resolution of 10 meters, including blue, green, red and near-infrared (NIR), enabled the generation of NDVI and Land Use/Land Cover (LULC) maps for the study area.

METHODOLOGY

Fruit Crop Diversity: The coordinates of the orchards were recorded with a Garmin GPSMAP 64s receiver (WGS84 datum) which were then imported as point locations in ArcGIS software**.** The fruit crop diversity map of the study area was prepared using the point data collected.

Correlation analysis of yield and weather parameters: The yearly production data of fruit crops were correlated with the weather parameters *viz.*, rainfall, minimum temperature and maximum temperature. The Karl Pearson correlation coefficient was obtained for the weather parameters with the production data of various fruit crops for the Nadaun block. The Karl Pearson coefficient was calculated with the following formula (Pearson, 1909):

$$r=\frac{\Sigma(X-\bar{X})\,(Y-\bar{Y})}{\sqrt{\Sigma(X-\bar{X})^2}\ \sqrt{\Sigma(Y-\bar{Y})^2}}$$

Where, $\bar{X}$= mean of X variable

$\bar{Y}$= mean of Y variable

Normalized Difference Vegetation Index (NDVI) Calculation: NDVI of the study area was generated from reflectance of images for comparing and editing classification results. The Sentinel-2 (2B-2A) satellite data were used to generate NDVI maps of the study area. The map was reclassified using spatial analyst tool using the reclassify option into five classes in the ArcGIS software. Using the satellite data and ground truth information, the exact value of NDVI for threshold was generated. bands. The NDVI of imagery was calculated using the mathematical formula given below (Johansen and Tommervik, 2014):

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

The formula above indicates the values of NDVI are unit less and range in a scale with upper limit of +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, satellite image of the study area was classified using maximum likelihood classifier under supervised classification method. The three bands of Sentinel-2 data were used to generate the LULC classes viz., 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, agriculture 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.

RESULTS

Fruit crop diversity: The thematic map of the fruit crop diversity of the orchards visited during the survey of Nadaun block was prepared by placing point locations in the study area boundaries (Figure 2). The area under different fruit crops was calculated by drawing the boundaries of the orchards as polygons on Google Earth Explorer (table 1). It was observed that mango and citrus are the major fruit crops grown in Nadaun.

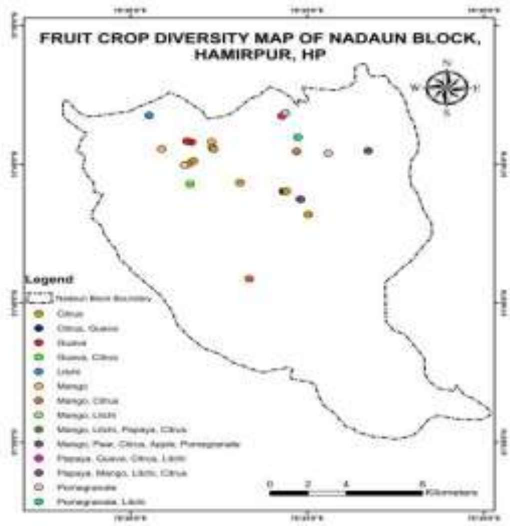

Fig 2. Fruit crop diversity map of Nadaun block

Table 1. Total area under different fruit crops in orchards surveyed

Fruit Crop	Area (sq.km.)	Area (%)
Mango	58254.42	33.49
Citrus	50297.49	28.92
Pomegranate	32561.16	18.72
Litchi	20612.23	11.86
Guava	7881.30	4.53
Papaya	2645.81	1.52
Pear	1311.99	0.75
Apple	350.79	0.21
Total	173915.19	100

Correlation analysis of fruit production data and weather parameters: The correlation analysis of the data from 2002-2021 for the past 20 years was worked out. Karl Pearson's Correlation Coefficients of the annual precipitation, minimum temperature and maximum temperature were checked with the production data of important fruit crops (Tables 2,3). From the correlation analysis, it was observed that the production of plum, peach, pear, mango, litchi, guava, papaya, citrus and pomegranate had a negative correlation with the change in rainfall pattern over the years. It was observed that the mean annual minimum and maximum temperatures did not show any significant correlation with the production of various fruit crops as the temperature had not shown any significant change over the selected years in the study area.

Table 2. Correlation between production of major fruit crops with annual rainfall (2002-2021) of Nadaun block

	RF	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
RF	1.000	-0.583^{**}	-0.524^{*}	-0.440^{NS}	-0.389^{NS}	-0.489^{*}	-0.583^{**}	-0.041^{NS}	-0.287^{NS}	-0.065^{NS}

RF = Rainfall, P_1 = Plum Production, P_2 = Peach Production, P_3 = Pear Production, P_4 = Mango Production, P_5 = Litchi Production, P_6 = Guava Production, P_7 = Papaya Production, P_8 = Citrus Production, P_9 = Pomegranate Production

Table 3. Correlation between mean annual minimum and maximum temperatures with production data of major fruit crops of Nadaun block

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
T_{max}	-	-	-	0.016^{NS}	0.239^{NS}	-	-	-	-

	0.302^{NS}	0.296^{NS}	0.175^{NS}			0.281^{NS}	0.106^{NS}	0.153^{NS}	0.085^{NS}
T_{min}	0.175^{NS}	0.128^{NS}	0.248^{NS}	-0.178^{NS}	0.153^{NS}	0.119^{NS}	0.250^{NS}	0.049^{NS}	0.012^{NS}

T_{min} = Minimum Temperature, T_{max}= Maximum Temperature P_1 = Plum Production, P_2 = Peach Production, P_3 = Pear Production, P_4 = Mango Production, P_5 = Litchi Production, P_6 = Guava Production, P_7 = Papaya Production, P_8 = Citrus Production, P_9 = Pomegranate Production

Normalized Difference Vegetation Index (NDVI) generation: The NDVI ranges are different for different classes of features on the ground. NDVI is an indicator of the density of chlorophyll and leaf tissue calculated from the red and near infrared bands (Sahebjalal and Dashtekian, 2013). NDVI of Nadaun (Figure 3) was found to be within the range of -0.85 to +0.95 (Table 5). The NDVI real values, by definition, would be between -1 and +1, where increasing positive values indicate increasing green vegetation and negative values indicate non-vegetated surface features such as water, barren land, ice, snow or clouds (Sahebjalal and Dashtekian, 2013).
The maximum area was under dense vegetation class i.e. 119.99 sq. km. while the non-vegetation class covered a minimum area of i.e. 2.54 sq.km. The area under very dense class was 102.52 sq.km., sparse vegetation class was 22.39 sq.km. and low vegetation class was 11.58 sq.km. (Table 4)

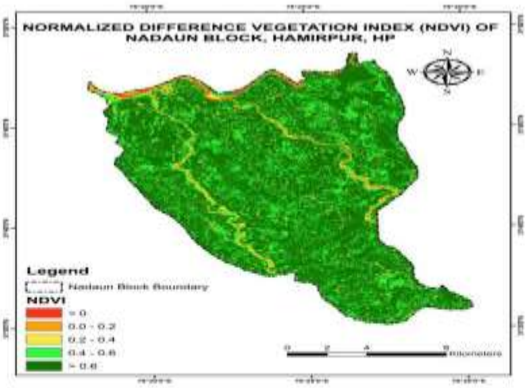

Fig 3. NDVI of Nadaun block

Table 4. Area under different classes of Normalized Difference Vegetation Index (NDVI) of Nadaun block

S.No.	Class	Vegetation Indices	Area (sq.km.)
1.	Non Vegetation Areas	< 0.1	2.54
2.	Low Vegetation Areas	0.1-0.3	11.58
3.	Sparse Vegetation Areas	0.3-0.5	22.39
4.	Dense Vegetation Areas	0.5-0.7	119.99
5.	Very Dense Vegetation Areas	0.7-1.0	102.52
Total			259.02

LULC Map: The Land Use Land Cover map of the study area was prepared using Sentinel 2 data (Figure 4). The Land Use Land Cover was categorized into five classes *viz*., tree cover, settlement, water body, agriculture land and other land (Table 5). Through the land use and cover mapping, it becomes possible to identify five different thematic classes in the study area (Vanesdsa et al., 2020). It was observed that maximum area was under agriculture land *i.e*. 31.11% (80.58 sq.km.) of the total land cover and the minimum area was under water body *i.e*. 2.48 % (6.42 sq.km.). The area under tree cover was 75.70 sq.km., the area under settlement was 29.90 sq.km. and the area under other lands is 66.42 sq.km.

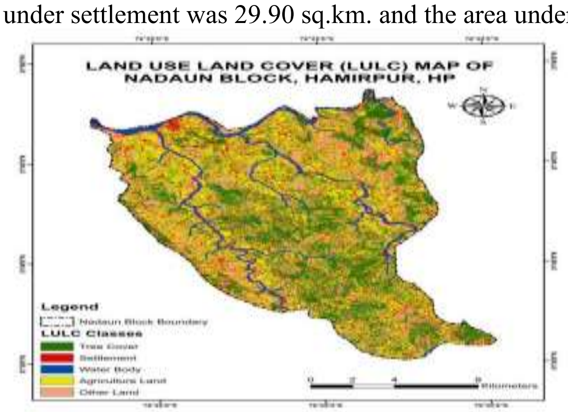

Fig 4. LULC map of Nadaun block

Table 5. Area under different classes of Land Use Land Cover (LULC) of Nadaun block

Land Use Category	Area Percentage (%)	Area (sq.km.)
Tree Cover	29.23	75.70

Settlement	11.54	29.90
Water Body	2.48	6.42
Agriculture Land	31.11	80.58
Other Land	25.64	66.42
Total	100	259.02

DISCUSSION

Fruit crops composition

The fruit diversity map and area statistics clearly indicate that mango and citrus form more than 60 percent of the surveyed orchard area in Nadaun. Pomegranate and litchi form the second tier and other fruits (guava, papaya, pear, apple) are minor components. This dominance of mango and citrus is in line with the recommendations for sub-tropical low hill zones of Himachal Pradesh where these fruits have been identified as the most promising commercial fruits under the prevailing agro-climatic conditions. Similarly, broader horticultural diversity surveys in Himachal Pradesh suggest that citrus, mango, guava and litchi are the main drivers of the expansion of subtropical fruit in districts with warm summers and mild winters such as Hamirpur.

Rain and fruit bearing

Correlation analysis over a 20 year period reveals a generally negative association of annual rainfall with production of most major fruit crops with a few correlations being statistically significant for plum, peach, guava, papaya and some other species. Such negative correlations suggest that inter-annual rainfall variability, particularly excess or poorly distributed rainfall, has tended to reduce yields instead of enhancing them. This is consistent with the findings from Jhalawar district where inter-annual and seasonal rainfall variability was identified as a major cause of fluctuations in fruit production. Correlation analyses have also indicated that in Haryana, fruit crops with decreasing temporal productivity trends are negatively and significantly correlated with one or more weather parameters, particularly rainfall (Khan, 2023). Several studies in the country have reported large yield losses for mango and citrus as a result of unseasonal pre-flowering and flowering-season rains, which increase disease incidence, disturb pollination and cause fruit drop (Sousa da Silva et al., 2023, Singh et al., 2014).

Dependence on temperature

In contrast, mean annual minimum and maximum temperatures had weak and non-significant correlation with fruit yields, which is in agreement with long-term climate analyses from Haryana and Himachal Pradesh showing modest shifts in mean temperatures compared with more pronounced changes in rainfall regimes (Bharti et al., 2023). Assessments of climate change for Solan district also indicate that for subtropical fruits such as galgal, mango, litchi and guava erratic rainfall and episodic extremes frequently have stronger production impacts than gradual mean temperature trends (Singh et al., 2014). Thus, the present analysis supports the view that in this agroclimatic belt it is the timing and distribution of rainfall which are more important for fruit production than gradual changes in mean temperatures.

Vegetation condition from NDVI

The NDVI analysis shows that most of the Nadaun block is covered by dense and very dense vegetation classes and only small fractions are classified as non-vegetated or low vegetation surfaces. NDVI values between 0.5 and 0.8 are generally considered to be indicative of vigorous and well-established vegetation cover (forest or prosperous cropland), while values above 0.8 are indicative of extremely dense and healthy canopy typical of humid forests or high-biomass systems (Rouse et al., 1974; NCAR, 2023). The observed range of NDVI values of approximately –0.85 to +0.95 and the preponderance of high positive values therefore indicate that the landscape contains a large amount of perennial and seasonal vegetation, with limited areas of bare soil, water or built-up surfaces.

Implications for land use and land cover

The LULC map indicates that a significant proportion of the block is covered by agriculture land and tree cover and a smaller proportion of settlements, water bodies and other lands, which further reinforces the idea of a predominantly agrarian and vegetated landscape. Similarly, the Annual Land Use and Land Cover Atlas of India characterizes the low hill districts of Himachal Pradesh as being dominated by cropland and mixed tree cover, with expanding horticulture superimposed on traditional agriculture-forest mosaics. Sector diagnostics of subtropical horticulture in Himachal Pradesh indicate that such mixed land-use patterns provide opportunities for perennial crop diversification and value addition, provided water resources, soil conservation and market linkages are properly managed. Here, the relatively high share of agricultural land and tree cover in Nadaun is favourable for perennial fruit systems, although the non-negligible share of "other land" indicates that patches of degraded, fallow or scrub land are still available for possible horticultural or agroforestry expansion.

Considerations for management and planning

From a management perspective, the dominance of mango and citrus orchard area and the evidenced sensitivity of these crops to rainfall variability suggest a greater emphasis on water management, micro-climate regulation and disease management in Nadaun's fruit sector. Extension guidelines of Himachal Pradesh suggest measures like improved drainage, protective irrigation, canopy management and timely fungicidal sprays to mitigate the adverse effects of heavy or unseasonal rains on flowering and fruit set in mango, citrus and guava. On a landscape scale, NDVI and LULC information can be combined to identify zones of stable dense vegetation and suitable combinations of land-use for further horticultural intensification, while avoiding over-expansion of intensive horticulture into fragile or water-scarce zones (NCAR, 2023).

CONCLUSION

The fruit crop diversity maps showed a major area under the cultivation of mango and citrus while a minimal area was found under the cultivation of other fruit crops like plum, peach, pear, litchi, guava, etc. Further studies need to be carried out to identify potential fruit crops and areas suitable for cultivation of such fruit crops which can offer more profit to farmers. It can be concluded that the weather parameters *viz*., rainfall, maximum temperature and minimum temperature of specific regions need to be recorded with accuracy to study the detailed effect of the change in these weather parameters on the production of fruit crops in the region over the years. The NDVI revealed that majority of area was under dense vegetation class which happens to be the agriculture land and sparse tree plantations. LULC map of the study area also reveal that there is a substantial amount of land under agriculture and other lands that offers an opportunity to increase the area under fruit crop production after identifying the suitable and potential areas.

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Authors' Contribution
AS conceived the study design, performed data curation, the statistical analysis and interpreted the results. VKS contributed to methodology development and visualisation. AS wrote the original draft and reviewed the literature. YT curated data and assisted in formal analysis. YT contributed to software validation and resources. VKS supervised the study and provided resources. SM and AS reviewed and edited the final manuscript. All authors read and approved the final manuscript.

Compliance with Ethical Standards
Conflict of Interest: Authors do not have any conflict of interest to declare.

Ethical Issues: None

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