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Forecasting of Banana Crop Productivity Using Geospatial Approach: A Case Study of Anand District †

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Abstract: Banana is one of the main fruit crops in the world as it has gained importance in the global market due to its high source of nutrients and fibre content for many industries. Owing to climate change and irregular precipitation, the yield of banana crops is becoming very unpredictable and thus, there is a need to understand the impact of climatic parameters on the yield. Mathematical models are crucial for strategic and forecasting applications; however, models related to the banana crop are less common, and reviews on previous modelling efforts are scarce, emphasizing the need for evidence-based studies on this topic. This study employs the geospatial approach to establish a relationship between climatic variables and banana crop productivity of Anand district of Gujarat, India. Sentinel data was utilized to derive various indices like Normalised Difference Vegetation Index (NDVI), Leaf Area Index (LAI), Enhanced Vegetation Index (EVI) and Normalised Difference Water Index (NDWI). Land Surface Temperature (LST) was also derived using Landsat dataset. Evapotranspiration (ET) data was also considered while understanding the impact of these parameters on yield. Values were extracted based on the ground control points (GCP) of different agricultural fields of study area. Derived data was analysed using different statistical tools to understand the relationship between different indices and productivity of banana crop. Results indicated that the banana yield is highly dependent on water availability and ET of the study area proving that these parameters can be utilized for generating predicting models of banana yield.

Keywords: banana; sentinel data; landsat; EVI; NDWI; Evapotranspiration

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1. Introduction

India is a well-diverse country with wide variety of agricultural products owing to its different climatic conditions. Banana ranks second amongst fruit consumption in India after mango due to its low price and high nutritive value [1]. The area under the banana cultivation has increased up to 880 thousand hectares with a production of approximately 35 million metric tons in 2022 [2]. The leading producers of bananas are Tamil Nadu, Maharashtra, and Gujarat states of India indicating their important contribution in banana crop production. Anand is one of the important banana producing districts of Gujarat and contribute significantly in total banana production of the state. However, latest data of year 2022 shows that farmers are turning to other fruit crops because banana is a water-intensive crop and water levels across the state are declining. In addition to this, overall yield of banana is decreasing due to climate change and irregular precipitation and it is getting worse day by day. In contrast to this, the demand of banana is increasing gradually due to its high nutritive value and affordable rates.

Accurate predictions of crop production are critical for developing effective strategies at the farm level [3]. Prediction of banana crop yield therefore, becomes imperative

given the fact that its importance is increasing incredibly. Availability of different type of spatial data makes it easy to carry out geospatial analysis and understand the impact of different ecological factors on the banana crop. This study utilized various parameters like Normalized Difference Water Index (NDWI), Land Surface Temperature (LST), Evapotranspiration (ET), Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), and Leaf Area Index (LAI) to forecast banana yield of Anand district. In this study LAI is considered as a proxy for the banana yield as high LAI indicates healthy crop and high production. Modelling carried out using different techniques help in understanding the impact of various parameters on crop yield and generating the accurate models for the prediction. Among the different models, a mathematical model provides a description of the behaviour of real-world systems in mathematical concepts, terms, and languages such as equations, inequalities, functions, variables and constraints [4]. Moreover, these models allow for making crop predictions under specific environmental conditions [5].

Therefore, this study attempts to utilize geospatial approach to forecast the banana crop yield of Anand district of Gujarat using mathematical modeling.

2. Study Area

Anand is primarily an agricultural district of Gujarat State of India (Figure 1). As per climatological data of nearest Indian Meteorological Department (IMD) Station at Ahmedabad the summers are generally hot and winters are cool. Mean maximum temperature ranges between 28.4 °C during January to about 41.8 °C during May and the mean minimum temperatures vary between 11.7 °C during January and 27 °C during June. Long-term average annual rainfall for Ahmedabad IMD station is 799.6 mm. Most of the rainfall is received during south-west monsoon between June and September [6]. Banana is one of the key crops grown in the district in terms of its value. The planting season of banana varies between Mid-February to first week of March. More than 10,000 Ha land is under banana cultivation and since it is an annual crop and needs more investment, even scale of finance for banana cultivation is reasonably high.

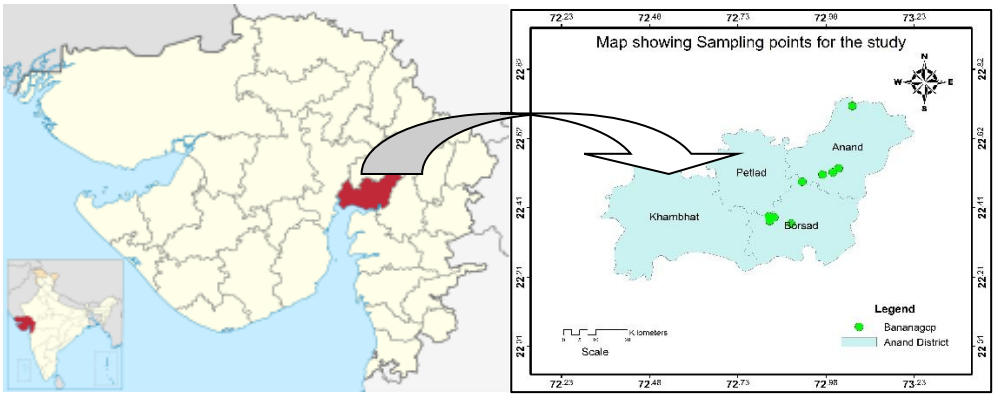

Figure 1. Map of Study area.

3. Methodology and Material

Banana crop yield forecasting needs different parameters to be assessed to understand their impact on yield. Field study was carried out in Anand district to locate banana fields and Ground Control Points (GCP) were collected. Total 11 different fields were identified which covered the different parts of the district. Study duration for the study was from January 2018 to December 2021 for all the parameters. Sentinel 2 data was utilized to derive various indices like NDVI, EVI and NDWI. LAI was derived from EVI using the following formula:

$$LAI = (3.618 \times EVI - 0.118)$$

LST was also derived using Landsat dataset after processing using ERDAS 9.1. ET data was also extracted from MODIS satellite data. Sentinel 2 data has repetivity of every eight days whereas, MODIS satellite data has the repetivity of 15 days. Data for both the satellite collected from January 2018 to December 2021 was averaged out monthly post which values were extracted corresponding to GCPs using ENVI 5.1 software. Various statistical methods like regression, *t*-test, etc. were utilized to understand the impact of different parameters on yield of Banana and to forecast the yield.

4. Result and Discussion

Agricultural production is significantly affected by environmental factors. Weather influences crop growth and development, causing large intra-seasonal yield variability. Anand district which is located in the central Gujarat shows significant variations in various environmental parameters. Application of geospatial approach helps in easy derivation of these parameters for a long timeseries [7]. derived geospatially Various parameters considered for the study showed a significant seasonal variation during the study period. LST varied from 8 °C in winter to 43 °C in summer indicating the year round variations in temperature (Figure 2). NDWI was found to be varied from −1.41 to −0.28 indicating the variation in water regime of the agriculture fields (Figure 3). Low NDWI values were observed from January to June months corresponding to the dry season of the year. EVI varied from 0.09 to 0.82 during the study period (Figure 4). Correspondingly, LAI of the banana crop varied from 0.19 to 2.85 indicating the vigour of the crop (Figure 5). EVI and LAI were found to be high during the months of February to July months of the year representing plantation period of the banana crop. NDVI values were found to be varied from 0.14 to 0.58, wherein high values indicated the growing season of banana crop (Figure 6). ET varied from 0.1 to 2.41 mm day^{-1} revealing its seasonal variation (Figure 7). It showed higher values during monsoon season indicating its role in crop growth.

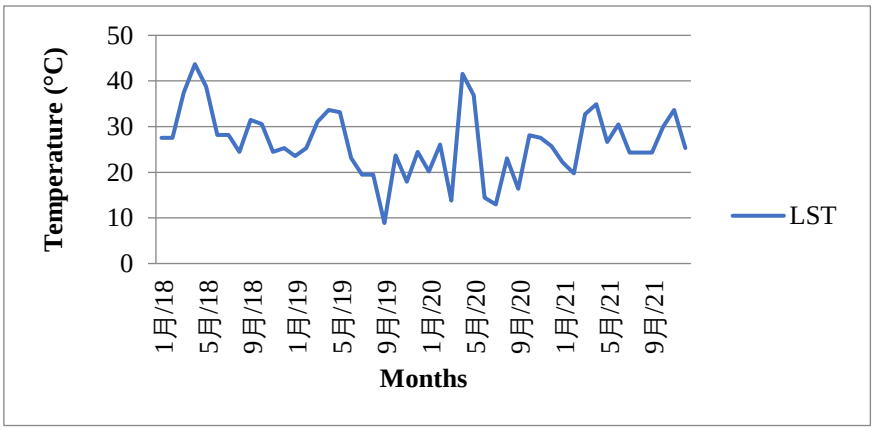

Figure 2. Graph showing variation in LST during the study period.

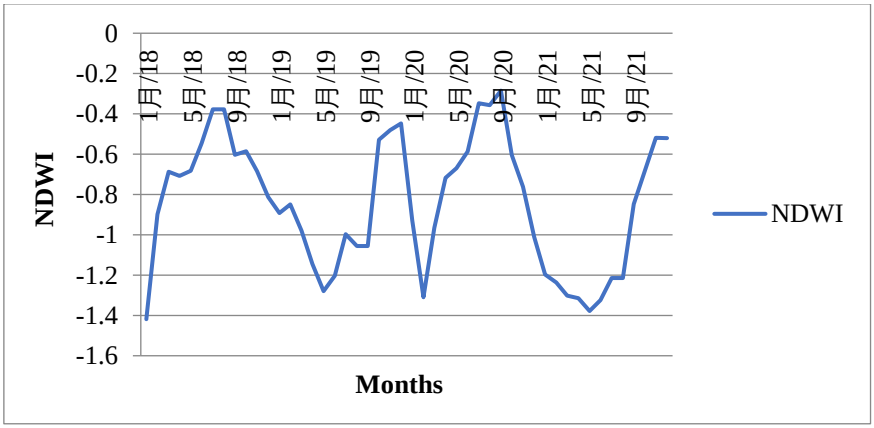

Figure 3. Graph showing variation in NDWI during the study period.

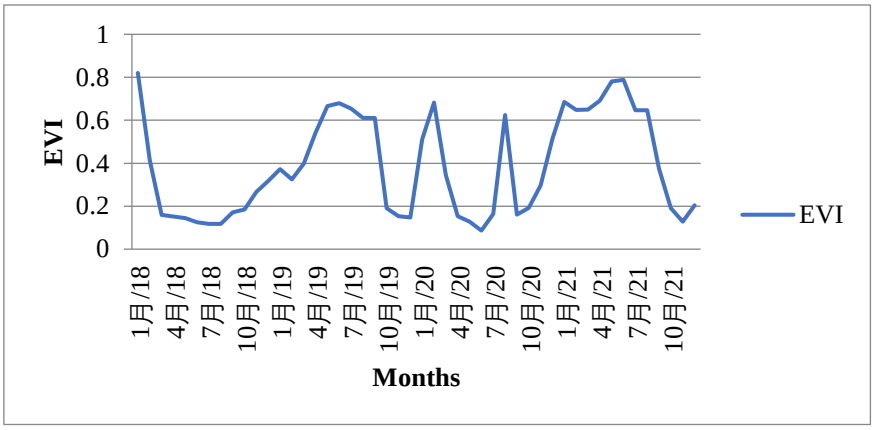

Figure 4. Graph showing variation in EVI during the study period.

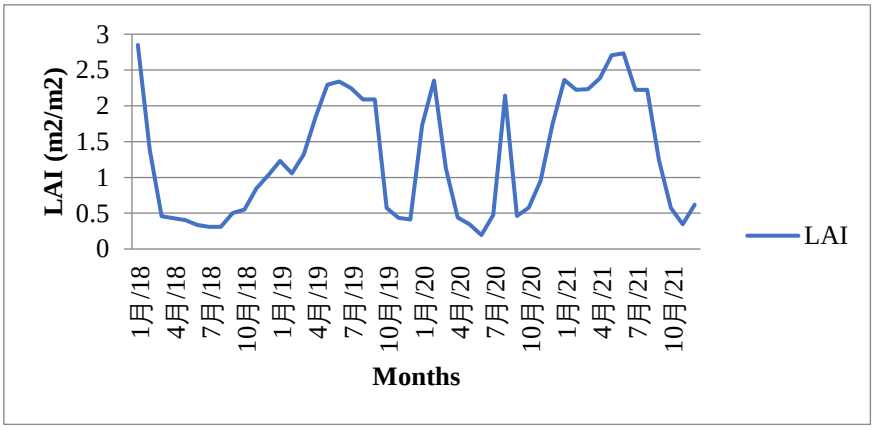

Figure 5. Graph showing variation in LAI during the study period.

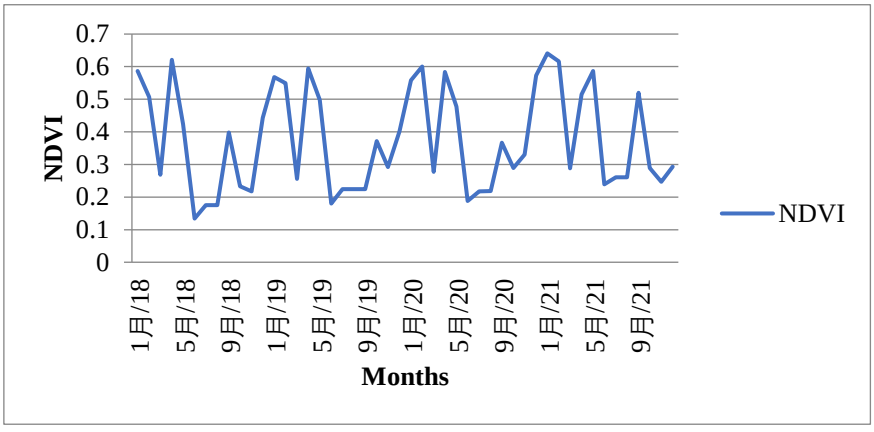

Figure 6. Graph showing variation in NDVI during the study period.

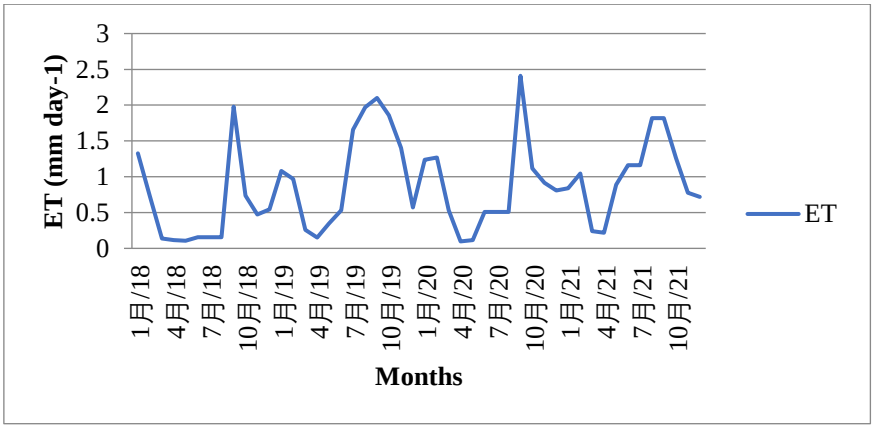

Figure 7. Graph showing variation in ET during the study period.

Values derived from these parameters were analysed statistically to understand the relationship between different parameters. The regression analysis between different parameters revealed an interesting result. It was clear from the analysis that since R^2 was only 0.02, therefore LAI was not dependent on LST indicating that the temperature variations were having less impact on crop growth. The ET and LAI were also poorly related with each other with R^2 value as low as 0.01. However, the crop was dependent on NDVI as revealed by R^2 value of 0.64 when regressed with LAI. EVI also played a major role in crop growth as it was the main parameter with LAI. Regression analysis between NDWI and LAI showed that these two variables were highly dependent on each other with R^2 value as high as 0.76. This indicated that the growth of banana crop was highly influenced by NDWI and yield of the crop varied with varying values of NDWI. These results were also supported by T-test.

Therefore, regression model derived using these two parameters were found to be significant for forecasting the banana yield (Figure 8).

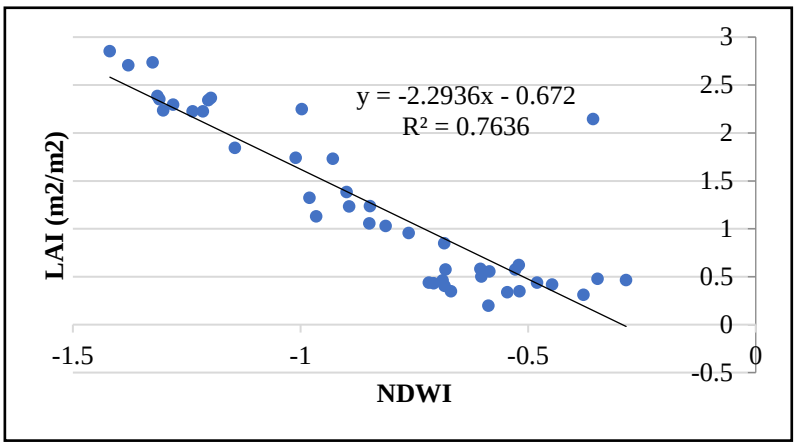

Figure 8. Chart showing regression equation for predicting Banana yield.

5. Conclusions

Banana is a one of the most important fruit crop of India and at global level. Increased water stress due to unpredicted rainfall and competition for water resources is leading to reduced yield of the crop. This study attempted to generate banana crop productivity based on the various parameters derived using geospatial approach. Regression analysis revealed that banana crop is highly dependent on NDWI, i.e., ground water condition of the agriculture field as indicated by high R^2 values. Regression model derived using these parameters can be utilized to predict banana yield.

Supplementary Materials: The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Figure S1: title; Table S1: title; Video S1: title.

Author Contributions: Conceptualization, U.P. and A.M.; methodology, U.P.; software, A.M.; validation, U.P, A.M. and A.G.; formal analysis, A.G.; resources, A.M., writing—original draft preparation, U.P.; writing—review and editing, U.P., A.M. and A.G. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: This study has been used Sentinel-2 multispectral imagery that is publically available at https://scihub.copernicus.eu/. and Landsat-8 multispectral imagery that is publically available at http://earthexplorer.usgs.gov.

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

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