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Fighting the Harvest Crisis: Investigating the Basmati Rice Decline in Dehradun's Rural Area

Himanshu Sahu[*a,b], Preeti Jakhwal[c], Pooja Purohit[b,c]

[a]Department of Population Management, Capture & Rehabilitation, Wildlife Institute of India, Chandramani, Dehradun – 248001, India

[b]Bhomya Foundation, Monal Enclave, Near Kargi Chowk, Dehradun – 248001, India

[c]School of Environment and Natural Resources, Doon University, Dehradun – 248001, India

[*]Corresponding author: Himanshusahudehradun@gmail.com

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***Abstract*: This article examines the challenges confronting Basmati rice cultivation in Dehradun, with a focus on climate change, land use shifts, market dynamics, and pest infestations. Analyzing the decline in Basmati rice production, the study employs remote sensing, GIS, and climate data analysis to identify the complex web of issues. Results highlight climate-induced variations, changing land use patterns, market dynamics, and pest-related threats. The article concludes by emphasizing a knowledge gap, especially among the youth, and highlights the need for interventions to make agriculture more appealing and sustainable. Collaborative efforts and innovative solutions are crucial for revitalizing Basmati rice cultivation in Dehradun, ensuring a resilient agricultural future.**

***Keywords*: Agriculture; Basmati rice; Climate change; Land use change; Market dynamics**

I. INTRODUCTION

Rice, scientifically known as *Oryza sativa* L., represents a fundamental dietary component for approximately half of the global population, contributing to over 20% of the total caloric intake (Shrestha et al. 2020). Notably, 40±80% of caloric consumption in Asian diets is derived from rice, particularly in the region where 95% of the world's rice is cultivated and consumed, namely Asia (Bhattacharjee et al., 2002). As a pivotal global staple, rice, and especially basmati, is gaining traction as an organic product due to its export potential. Basmati rice's appeal lies in its exceptional characteristics, including elongated grains, delightful fragrance, superb cooking quality, sweet flavour, and tenderness upon cooking. In the context of Indian traditions, aromatic rice holds not only superior quality but also cultural significance, symbolizing auspiciousness. The term Basmati, derived from *Bas* (aroma), collectively encompasses various aromatic rice varieties cherished not only in Asia but also in Europe and the United States (Bhattacharjee et al., 2002). Despite the availability of over 5000 rice varieties worldwide, Basmati's unique attributes have elevated its popularity (Bhattacharjee et al., 2002). Originating in the 19th century, Basmati rice has seen the development of numerous varieties, with the Indian Himalayas remaining a prime cultivation site. Dehradooni Basmati rice, grown south of the Ganges River and north of the Yamuna River in the Indian Himalayas, is particularly renowned for its rich aroma and lengthy grains (Mishra, 2021). However, this specific variety faces challenges, including diminishing cultivation areas due to rapid urbanization and the absence of marketing facilities and government support (Joshi, 2018). Factors such as hybridization, urbanization, pollution, and insufficient marketing support have also contributed to the decline of basmati varieties (Azad, 2014). Analysing basmati rice trends in India and Haryana, Rju and Kumar (2019) found a decline in area, productivity, and production from 2009–10 to 2018-19. The districts of Karnal and Kaithal witnessed specific attention. Haryana experienced a decrease in basmati rice area and output but an increase in yield during this period (Rju and Kumar, 2019). Uttarakhand, contributing 1.34% of India's basmati production in 2010–11, faced a continuous decline, reaching 0.74% in 2018–19 (Rju and Kumar, 2019). This decline is attributed to factors such as high climatic unpredictability, migration leading to changes in agricultural patterns, and decreased crop productivity (Sati, 2020). The Himalayan state's rural population, facing significant migration to urban areas, has resulted in altered land usage and agricultural practices (Sati, 2020). Despite challenges, efforts are being made to revitalize basmati cultivation through the brand establishment, quality control labs, exhibitions, fairs, and subsidies (Joshi, 2018).

II. Materials and Methods

Study Area

The study is being carried out in the Indian state of Uttarakhand's northern district, Dehradun. Dehradun district has an interesting geographical backdrop, encompassing a broad range of topographies from the foothills of the Shivalik range to the plains of the Terai region. The focus point of this study is the administrative centre, Dehradun City, with peri-urban, urban, and rural areas surrounding it. The research region is ideal for examining a range of environmental, socioeconomic, and agricultural issues because of its distinctive combination of manmade and natural features. Rich agricultural landscapes and the urban impact of Dehradun City offer a comprehensive environment for studying socioeconomic factors, land-use patterns, and regional dynamics.

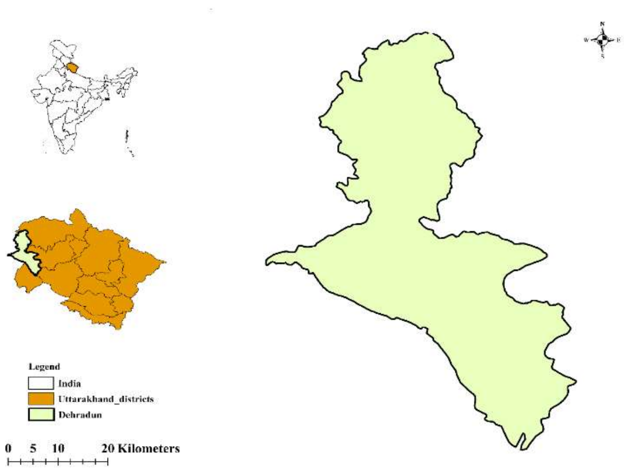

Figure 1. Map showing the intensive study area

Dataset and Methods to Determine Climate Change (Temperature and Precipitation)

This study employs a scientific methodology to analyse climate trends utilizing temperature and precipitation data sourced from the Google Earth Engine (GEE) platform, with a focus on elucidating long-term patterns for valuable insights into climate research. The dataset, spanning from January 1991 to December 2021, encompasses decadal temperature and precipitation information derived from satellite observations, characterized by a monthly spatial resolution. Data collection involved precise querying of the GEE database through the GEE Python API, specifying parameters such as the location of the study area, and climatic variables (Temperature and Precipitation) (Yin et al., 2020). The raw time series data for temperature and precipitation underwent a meticulous decomposition into trends using Excel. Subsequent data processing and analysis were executed through the GEE Python API, complemented by Excel for time series creation. This integrated approach ensures a rigorous examination of climate trends, aligning with the scientific standards requisite for contributing robust insights to the field of climate research.

Data Set and Methods (LULC)

The study conducted by Bhat et al. (2017) employed diverse datasets, incorporating Survey of India (SOI) toposheets at a scale of 1:50,000 (No. 53 J/11) and Indian Remote Sensing (IRS) LISS-IV images for the years 2004 and 2014. To comprehend dynamic phenomena such as urban sprawl and growth, the research necessitated land use change analyses. ERDAS (Leica) and ArcGIS software (ESRI) were utilized to generate various thematic layers, including land use maps, road maps, and railway lines using the toposheets and other available maps. The detailed methodology for this analysis is presented in **Figure 2.**, providing a structured framework for understanding the procedures employed in the study for land use change analysis and mapping, with specific emphasis on the integration of SOI toposheets and IRS LISS-IV images using advanced geospatial software tools (Bhat et al., 2017).

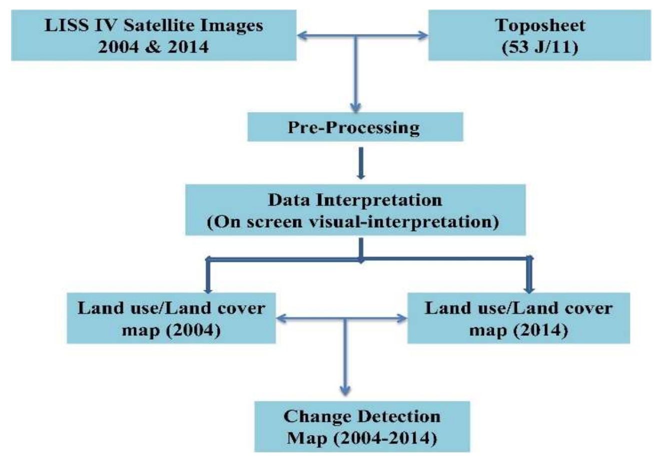

Figure 2. Flow chart of Methodology followed by Bhat et al. (2017)

Dataset and Methods (NDVI)

We analysed vegetation dynamics within a designated region using the Normalized Difference Vegetation Index (NDVI), a key indicator of vegetation health derived from Landsat-8 satellite imagery available on GEE. The study period spans from January 2014 to December 2023, and the chosen region is defined using a shapefile to ensure specificity. The NDVI is calculated using Landsat-8's near-infrared (NIR) and red bands, applying the standard formula (Equation 1). Leveraging Google Earth Engine's pre-processed satellite data, we simplify the NDVI calculation process. Time-series imagery is collected for the region of interest (ROI), with Landsat-8 datasets offering multispectral capabilities (Liu et al., 2023). The selection criteria for imagery include cloud cover filtering and preprocessing steps to enhance data quality. The derived NDVI time series is subject to cross-validation techniques to assess accuracy, ensuring the reliability of our insights into changes in land cover and vegetation dynamics over the specified temporal range within the defined landscape.

$$(NIR - R) / (NIR + R) \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{ Equation 1}$$

III. RESULTS AND DISCUSSIONS

Climate Trend

Climate change

Climate change poses a significant threat to rice production because it modifies temperature, precipitation patterns, water availability, and carbon dioxide concentration. An increase in temperature and a decrease in precipitation lead to a decline in basmati rice. Since more than half of the world's population depends on rice for their main diet, rice production plays a significant role in ensuring global food security. There are many ways in which climate change affects, in that temperature is one; in rice production since it has an impact on photosynthesis, respiration, transpiration, and flowering, among other physiological functions of rice plants. Rice output may suffer as a result of rising average and high temperatures brought on by climate change. For instance, elevated temperatures can lead to heat stress and sterility in rice plants, decrease photosynthetic efficiency, and increase water loss. Rainfall is another factor that hinders rice production since it changes the soil's moisture content, water availability, and flooding circumstances. Rainfall patterns, including their quantity, distribution, frequency, and severity, can vary as a result of climate change. Variations in rainfall can have an impact on rice fields' water balance, nutritional availability, and insect and disease occurrence. Variations in rainfall can also result in issues with salinization, floods, and waterlogging, all of which can harm rice fields and lower yields.

We calculated the average temperature and average rainfall from 1991-2021, and we found that temperature is increasing gradually, and precipitation is decreasing. In the year 2016 temperature was at a peak of 28.97, and in the same year precipitation was 258.25. According to the study conducted by (Baliarsingh et al., 2018)in Orisha's Puri region, stated that there were fluctuations in the amount of rainfall for each block during the course of the study's twenty-two-year period (1993–2014). In addition, there were fluctuations in the district's rainfall and rice output throughout the thirty-four-year period (1981–2014). A negative rainfall shock has a significant impact on productivity in agriculture. A negative shock to rainfall causes a 38% decrease in agricultural yield. This may be due to the fact that crop production risks posed by rainfall shocks raise the possibility of farm technology adoption, which in turn lowers production and productivity (Barrios et al., 2010; Brown et al., 2010; Christiaensen et al., 2011; Falco and Chavas, 2009). This risk is especially high in rainfed, liquidity-constrained, and imperfect market settings. These findings also support earlier research (Christiaensen et al., 2011; Falco and Chavas, 2009), which demonstrates that farmers' decisions about the use of external inputs that increase productivity are influenced by rainfall variability, which also raises the possibility of crop loss, which has an impact on agricultural productivity.

Land use

Land use calculation using Remote sensing and GIS

GIS is an organized method for gathering and analysing spatial data. By monitoring and evaluating the changes in the environment and making predictions based on the current circumstances, it can be utilized to research the environment (Ramachandra and Kumar, 2004). Remote sensing is the technique of gathering data using airborne or space-based sensors without coming into touch with the target objects. It makes it possible to collect multispectral, multiresolution, and multitemporal data for the modeling and study of land use change. Remote sensing techniques are frequently utilized for change detection analysis because of their affordability and temporal frequency (Im et al., 2008).

The classes of urban and built-up, fallow, and forest land showed positive changes, while the classes of forest, agriculture, mixed vegetation, and riverbed showed negative changes. From 2004 to 2014, the urban and built-up areas grew by 8.40 percent, from 27.16 to 34.08 km^2. 6.13 km^2 of agricultural, fallow, and unoccupied land was lost to the built-up area between 2004 and 2014, according to the study, demonstrating a notable urban sprawl in and around the city(Bhat et al., 2017). These results indicate that the layout and structure of urban features in the studied area have changed significantly. The sprawl measurement's findings show that, between 2004 and 2014, there was a high rate of sprawl and dispersed urban development. The urban fringe would therefore be significantly impacted by this in return. The agricultural area has experienced a notable shift, with a 9.47 percent negative growth rate. Between 2004 and 2014, it shrank by around 39%, from 25.45 sq. km to 17.65 sq. km. The majority of it is made up of mixed vegetation, fallow land, unoccupied land, and urban and built-up areas. Among these eight classifications, forests barely accounted for 2.13 Km^2 in 2014, compared to roughly 2.54 Km^2 in 2004, indicating a growth rate of less than 0.50 percent (Bhat et al., 2017). One could classify this area as environmentally preserved.

Normalized Difference Vegetation Index (NDVI)

After 2014 we calculated the NDVI of the area and found that NDVI from 2014 to 2023 shows a gradual decrease in the vegetation. It is suggested that the effects of climate change would change the relationship between agricultural areas and the primary production of vital crops (Wheat, Barley, Rice, Maize, and Sunflower). Iraq is one of the world's semi-arid regions, according to the Intergovernmental Panel on Climate Change (IPCC) assessment, and it has recently been marked by a lack of water and a restricted area suitable for agriculture.

TABLE 1
Average Annual Temperature and Amount of Precipitation for 1992-2021

Year	Annual Average Temperature	Annual Average Precipitation	Year	Annual Average Temperature	Annual Average Precipitation	Year	Annual Average Temperature	Annual Average Precipitation
1992	26.96	238.8	2002	28.07	249.5	2012	27.22	241.2
1993	27.51	244.3	2003	27.67	244.67	2013	27.53	244.5
1994	27.43	243.1	2004	28.73	255.58	2014	27.26	241.3
1995	27.18	240.2	2005	27.46	242.83	2015	27.39	242.8
1996	27.39	242.7	2006	27.89	248.92	2016	28.91	258.3
1997	26.28	232.6	2007	28.16	250.83	2017	28.28	251.9
1998	27.36	242.9	2008	27.63	244.83	2018	28.14	250.5
1999	28.24	251.5	2009	28.33	251.67	2019	27.94	245.8
2000	27.88	248	2010	28.56	254.08	2020	27.61	246.5
2001	27.84	248.2	2011	27.72	246.42	2021	28.67	252.3

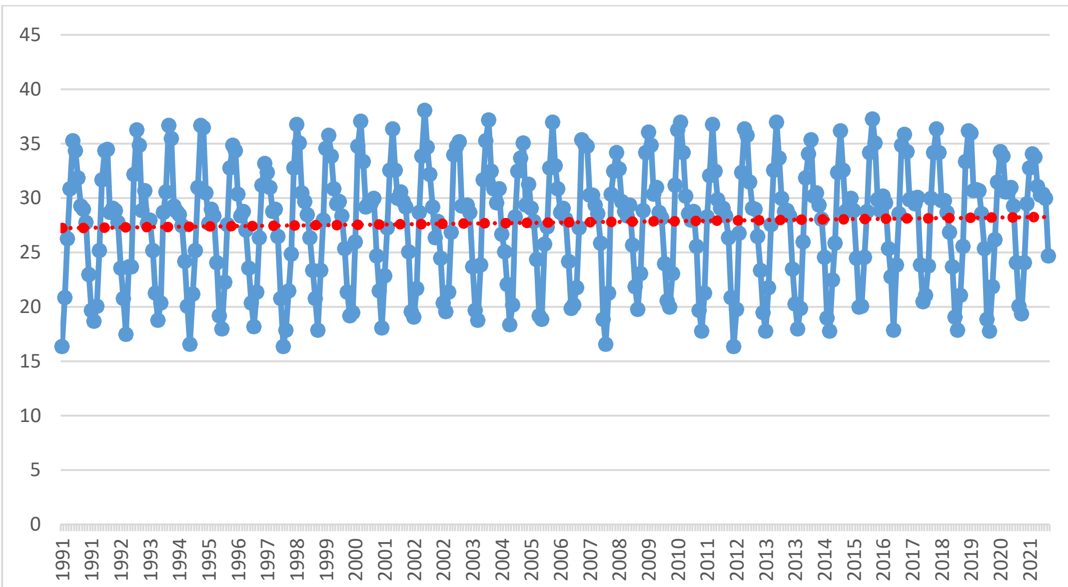

Figure 3. Time Series of Temperature from 1991-2021 using GEE

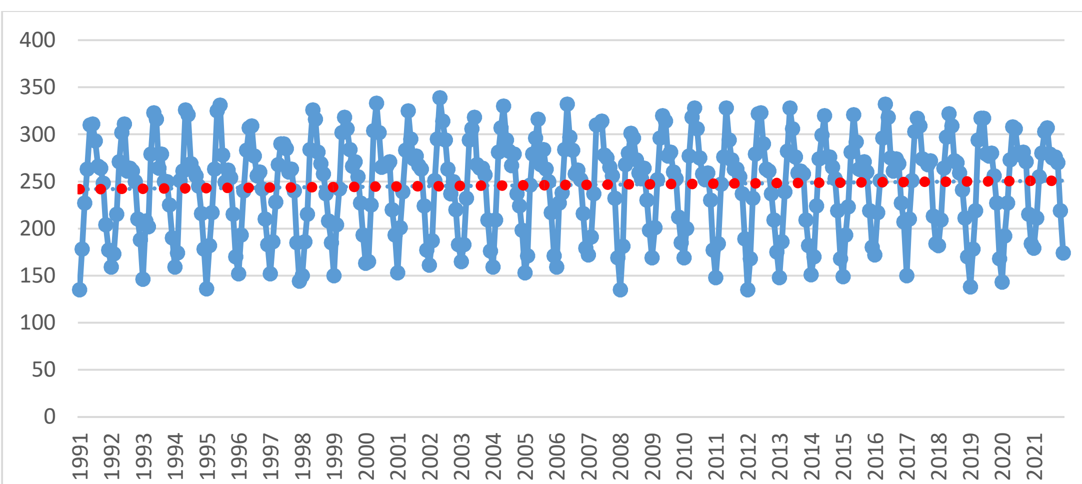

Figure 4. Time Series of Precipitation from 1991-2021 using GEE

One factor contributing to the alteration of land cover is the expansion of agricultural lands, which has a detrimental effect on natural resources such as grassland regions, which have declined due to the rise of irrigated agriculture in Japan's Aso Caldera (Amano and Iwasaki, 2020). The research area's grassland areas impacted by altered farming practices and altered water circulation due to varying groundwater recharge were identified using the NDVI and GIS software(Amano and Iwasaki, 2020). A study conducted in the Krishna district of Andhra Pradesh's Vijayawada revealed that the primary drivers of the change in land cover between 2014 and 2020 were determined utilizing the NDVI technique and GIS technologies (Somayajula et al., 2021). For winter crops like wheat and barley, crop productivity was strongly correlated with yearly precipitation (59–63%), but for summer crops like rice, maize, and sunflower, crop output was less susceptible to temperature (20–40%) (Jabal et al., 2022). The study was conducted in Varanasi and found that analysis of remotely sensed data collected over 20 years, between 1993 and 2013, the built-up area rose by roughly 345% while the amount of greenery declined by 86%(Patel et al., 2019). In contrast to what has been observed elsewhere, changes in land use brought about by urban growth have increased both the built area and the agricultural class. Between 1991 and 2011, the area under cultivation expanded by 39%, while the population density went from 1217 to 1806 people/km2, and the housing density increased from 152 to 273 households/km2. According to the vegetation delineation, between 1993 and 2013, dense vegetation fell from 28.4 to 1.7 km2, while sparse vegetation increased from 40.2 to 90.1 km2. There was a noticeable change in the main economic activity from agriculture to non-agricultural activities(Patel et al., 2019).

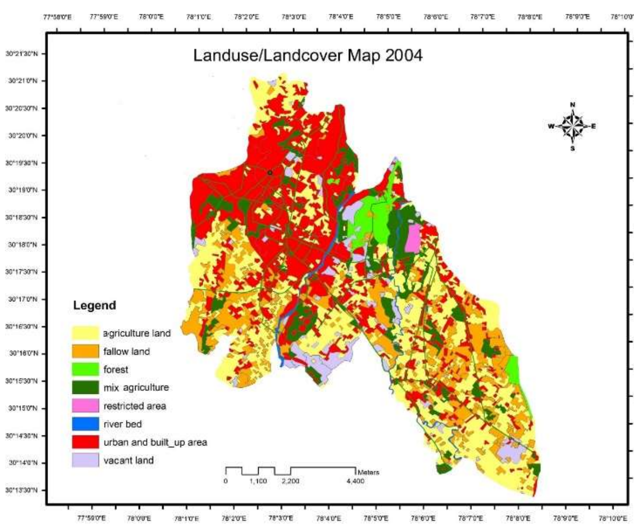

Figure 5. LULC Map of 2004 followed by Bhat et al. (2017)

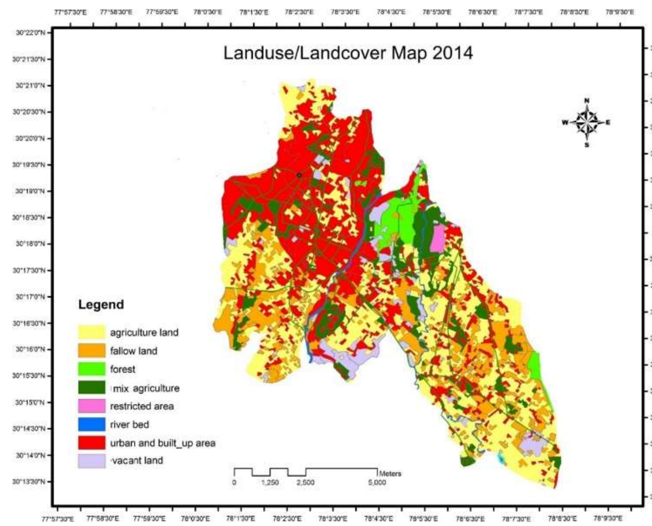

Figure 6. LULC Map of 2014 followed by Bhat et al. (2017)

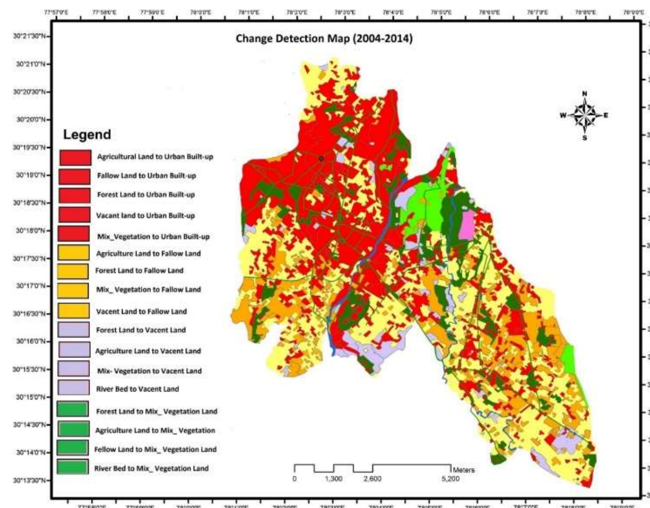

Figure 7. LULC change detection Map of 2004-2014 followed by Bhat et al. (2017)

NDVI

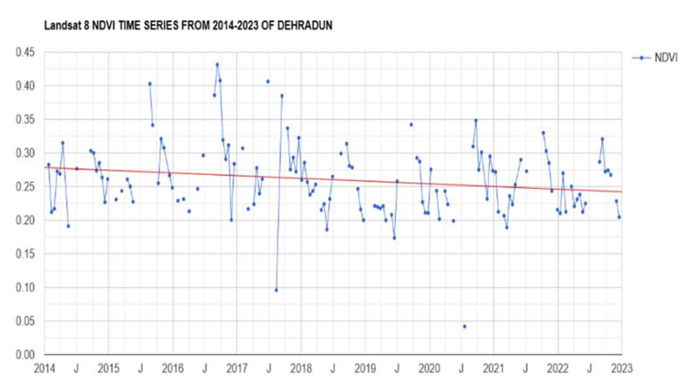

Figure 8. Landsat 8 NDVI time series for Dehradun District from 2014 to 2023

Market Dynamics

The amount of rice exported from India is significantly impacted negatively by domestic consumption. Less surplus is available for export when domestic consumption rises, and eventually, exports decline. A similar viewpoint has been endorsed by Bilal and Rizvi (2013). However, there has been a noticeable shift in people's eating patterns in recent years. India's intake of cereals is declining as a result of rising dietary preferences for processed meals, vegetables, and foods high in protein ((Kasztelan, 2017). It has been demonstrated that contract farming assists farmers in implementing new technology, increasing productivity, and producing higher-quality goods that increase exports. It also serves as a just and equitable means of compensation for the farming community. It gives farmers access to technology, high-quality inputs, and scientific guidance on productive farming. It supports an open marketing system that pays farmers a premium. Farmers benefit from greater prices as a result. Additionally, contract farming can increase basmati rice production and trade. It was discovered that contract farming has a positive effect on basmati rice yield. Compared to non-contract farmers, contract farmers made greater money overall. The total cost of the inputs was somewhat compared to non-contract farms, higher on contract farms ((Kasztelan, 2017).

The most important agricultural export from India is basmati rice. In terms of quantity, value, and unit value, the overall rice export increased at a substantial and positive rate. The compound annual growth rate for basmati rice exports was 7% in physical terms and 12% in monetary terms, indicating greater prices were being provided in addition to inflation. In the fiscal year 2018–19, India's exports of basmati rice exceeded 32000 crores in value. From 2010–11 to 2019–20, Iran was the country that imported the most Basmati rice from India annually (28.5%), followed by Saudi Arabia (21.9%), the United Arab Emirates (11.48%), Iraq (8.55%), and Kuwait (6.02%) (Kumar et al., 2021). From 2010–11 to 2019–20, the price of a kilogram of Basmati rice fluctuated between Rs 47.90 and Rs 77.98. The implementation of policy requirements aimed at promoting rice export involves informing farmers about export potential and price trends, supporting the development of advanced irrigation systems, facilitating the advancement of technology for the management of pests, diseases, and insects, improving the quality of milling facilities to increase yield per ton, and promoting Indian Basmati rice brands in international market (Kasztelan, 2017). According to the study conducted by (Sharma et al., 2020), compares farmers farming basmati rice under conventional and fair-trade systems, aiming to find the most pertinent aspects and indicators for evaluating sustainability. The results indicate that the fair-trade system outperforms the conventional system in terms of sustainability, with governance being the main differentiator.

Pest Infection

In the western plain zone of Uttar Pradesh, the Crop Research Centre at Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.), India conducted research on insect pests related to basmati rice during the month of Kharif (July-November) 2014. Twelve insect species belonging to six orders—Lepidoptera (yellow stem borer, leaf folder, and swarming caterpillar), Homoptera (green leaf hopper, brown plant hopper, and white backed plant hopper), Heteroptera (rice gundhi bug), Coleoptera (rice root weevil and white grub), Isoptera (termite), and orthoptera (kharif grass hopper and grasshopper)—were discovered in this region in relation to basmati rice during the study period (Saini et al., 2015). An analysis of the prevalence of insect pests in the Basmati rice environment in western Uttar Pradesh, India, was acknowledged. Approximately 60% of the Western U.P. is dedicated to the cultivation of the Pusa Basmati-1121, Pusa Basmati-1, Pusa Basmati-6, Pusa Basmati-1509, and Vallabh-22 Basmati cultivars. Numerous insect pests infest the crop, which significantly reduces the amount of Basmati rice that is produced. The leaf folder and stem borer were determined to be at a significance level during the survey (Sharma et al., 2020).

Many insecticides have been used to control insect pests; however, overuse of pesticides has resulted in harmful ecological effects, residues in food products, and eventually pesticide resistance. The worldwide need for food free of pesticide residues and growing concerns about environmental safety have sparked a strong interest in environmentally friendly pest management techniques (Sharma et al., 2020). According to estimates, the annual loss resulting from insect pests is around 18% of the anticipated output of rice crops (Alam et al., 1983). According to Rockefeller Foundation research (Herdt, 1991), insect pests account for seven of the twenty main obstacles to rice production.

Gap of Knowledge

The prevailing decline in agricultural production can be attributed to a discernible knowledge gap, particularly evident among the youth demographic, stemming from an inadequate understanding or disinterest in agricultural pursuits. Various factors contribute to this phenomenon, with notable distinctions across countries. Capital constraints stand out as a common hurdle, impeding young individuals from venturing into agriculture due to difficulties in securing funds for essential components such as land, seeds, pesticides, fertilizers, machinery, and transportation. Furthermore, a deficiency in access to timely and accurate information exacerbates the issue, hindering the acquisition of knowledge crucial for adapting to dynamic environmental conditions, market demands, and technological advancements. The perception of low profitability and remuneration further discourages the youth from embracing agriculture, as it is often perceived as a low-status profession lacking adequate financial incentives. Societal norms and aspirations, particularly influenced by cultural factors, play a pivotal role in steering the preferences of young individuals away from agriculture. In this context, contemporary urban lifestyles are deemed more desirable, leading to aspirations misaligned with the agricultural sector. To rectify this knowledge gap, it is imperative to render agriculture more appealing and fulfilling for the youth. Strategic interventions encompass facilitating financial and resource access, providing comprehensive knowledge and instruction, ensuring participation in value chains and markets, and instituting rewards and recognition mechanisms. Addressing these aspects from a scientific perspective is essential for fostering a sustainable and vibrant agricultural future, one that attracts and retains the interest of the younger generation.

IV. Conclusion

The Basmati Rice decline in Dehradun is a tapestry woven with diverse threads, each requiring a nuanced and collaborative approach. As stakeholders navigate the challenges posed by climate change, water scarcity, pest infestations, changing land use, and market dynamics, a resilient agricultural landscape emerges. The revival of Basmati Rice cultivation in Dehradun demands not just solutions but a collective commitment to sustainable practices. In this pursuit, the region has the opportunity to redefine its agricultural narrative, marrying tradition with innovation, and securing a prosperous future for generations to come. The journey towards revitalizing Basmati Rice cultivation is not just a regional imperative; it's a testament to the resilience and adaptability of agriculture in the face of evolving challenges.

Recommendation: Potential Efforts for conserving Dehradun Basmati rice

1. **Climate Change Challenges:** Dehradun, like many regions globally, grapples with the intricate dance of climate change. The increasing frequency of erratic weather patterns, unpredictable rainfall, and temperature fluctuations poses a significant challenge to Basmati Rice cultivation. The intricate balance required for optimal growth is disrupted, leading to a ripple effect on yield and grain quality. To combat this, a strategic shift towards climate-resilient Basmati Rice varieties is imperative. Integrating modern agricultural practices, coupled with sustained research and development efforts, can birth varieties tailored to withstand the evolving climate.

2. **Water Management Strategies**: The quest for sustainable water management necessitates a two-pronged approach. Firstly, the implementation of precision irrigation techniques, guided by technology and local expertise, ensures the optimal use of water resources. Simultaneously, the promotion of rainwater harvesting becomes a community-driven initiative, aligning environmental conservation with agricultural vitality.

3. **Integrated Pest Management:** The battle against pests is an ongoing one, requiring continuous adaptation and innovation. Encouraging farmers to adopt integrated pest management approaches involves not just disseminating knowledge but actively involving them in research and development efforts. Collaborative platforms that bridge the gap between scientific advancements and on-ground implementation become imperative.

4. **Promotion of Sustainable Agriculture**: The preservation of agricultural land requires a paradigm shift in policy frameworks. Governments and local authorities need to champion sustainable agriculture practices, promoting organic farming and discouraging the conversion of agricultural land for non-agricultural purposes. Incentivizing sustainable practices becomes an investment in the future, safeguarding both the environment and agricultural heritage.

5. **Market Support and Price Stability:** Economic sustainability is the linchpin of agricultural resilience. Ensuring fair and stable prices for Basmati Rice in the market necessitates a collaborative effort. Government interventions, coupled with private sector initiatives, can create a market environment that rewards the toil of farmers. Improving market access through streamlined supply chains further empowers farmers, ensuring that Basmati Rice cultivation becomes not just a tradition but a thriving economic endeavor.

V. References

Alam, S., Karim, A. N. M. R., Alam, M. S., & Nurullah, C. M. (1983). Important rice insect pest control transferable to farmer's fields. In Proc. Workshop on Modern Rice Cultivation in Bangladesh, BRRI, Gazipur (pp. 106-116).

Amano, H., & Iwasaki, Y. (2020). Land cover classification by integrating NDVI time series and GIS data to evaluate water circulation in Aso caldera, Japan. International Journal of Environmental Research and Public Health, 17(18), 6605.

Baliarsingh, A., Nanda, A., & Mohapatra, A. K. B. (2018). Effect of rainfall and temperature on rice yield in Puri district of Odisha in India. Pharma Innov J, 7(4), 899-903.

Barrios, S., Bertinelli, L., & Strobl, E. (2010). Trends in rainfall and economic growth in Africa: A neglected cause of the African growth tragedy. *The Review of Economics and Statistics*, *92*(2), 350-366. https://doi.org/10.3390/ijerph17186605

Bhat, P. A., ul Shafiq, M., Mir, A. A., & Ahmed, P. (2017). Urban sprawl and its impact on landuse/land cover dynamics of Dehradun City, India. International Journal of Sustainable Built Environment, 6(2), 513-521. https://doi.org/10.1016/j.ijsbe.2017.10.003

Bhattacharjee, P., Singhal, R. S., & Kulkarni, P. R. (2002). Basmati rice: a review. International journal of food science & technology, 37(1), 1-12. https://doi.org/10.1046/j.1365-2621.2002.00541.x

Bilal, M., & Rizvi, S. B. (2013). Determinants of rice exports: An empirical analysis of Pakistan. Journal of Global and Scientific Issues, 1(4), 5-16.

Borgomeo, E., Vadheim, B., Woldeyes, F. B., Alamirew, T., Tamru, S., Charles, K. J., ... & Walker, O. (2018). The distributional and multi-sectoral impacts of rainfall shocks: Evidence from computable general equilibrium modelling for the Awash Basin, Ethiopia. *Ecological Economics*, *146*, 621-632. https://doi.org/10.1016/j.ecolecon.2017.11.038

Christiaensen, L., Demery, L., & Kuhl, J. (2011). The (evolving) role of agriculture in poverty reduction—An empirical perspective. *Journal of development economics*, *96*(2), 239-254. https://doi.org/https://doi.org/10.1016/j.jdeveco.2010.10.006

Deep Joshi (2018). Uttarakhand government moves to conserve fading Doon Basmati rice. Hindustan Times. https://www.hindustantimes.com/dehradun/uttarakhand-government-moves-to-conserve-fading-doon-basmati-rice/story-BkD9VLzUUuNqbD1JDuWDaN.html

Di Falco, S., & Chavas, J. P. (2009). On crop biodiversity, risk exposure, and food security in the highlands of Ethiopia. American Journal of Agricultural Economics, 91(3), 599-611. https://doi.org/10.1111/j.1467-8276.2009.01265.x

Herdt, R. W. (1991). Research priorities for rice biotechnology, in rice biotechnology. International Rice Research Institute, Manila, Philippines, 19-54.

Im, J., Jensen, J. R., & Tullis, J. A. (2008). Object-based change detection using correlation image analysis and image segmentation. *International journal of remote sensing*, *29*(2), 399-423.

Jabal, Z. K., Khayyun, T. S., & Alwan, I. A. (2022). Impact of climate change on crops productivity using MODIS-NDVI time series. Civil Engineering Journal, 8(06), 1136–1156. https://doi.org/10.28991/CEJ-2022-08-06-04

Kasztelan, A. (2017). Green growth, green economy and sustainable development: terminological and relational discourse. *Prague Economic Papers*, *26*(4), 487-499.

Kumar, V., Yadav, A., Kumar, A., & Singh, D. (2021). Magnitude, Direction and Determinants of Basmati Rice Export of India.

Liu, Z., Chen, Y., & Chen, C. (2023). Analysis of the Spatiotemporal Characteristics and Influencing Factors of the NDVI Based on the GEE Cloud Platform and Landsat Images. *Remote Sensing*, *15*(20), 4980.

Mishra, Yash (2021). From Basmati Rice to Cricket, Dehradun's Afghan Connection. Peepul Tree Stories. https://www.peepultree.world/livehistoryindia/story/religious-places-/dehraduns-afghan-connection

Patel, S. K., Verma, P., & Shankar Singh, G. (2019). Agricultural growth and land use land cover change in peri-urban India. Environmental monitoring and assessment, 191, 1-17. https://doi.org/10.1007/s10661-019-7736-1

Ramachandra, T. V., & Kumar, U. (2004, September). Geographic Resources Decision Support System for land use, land cover dynamics analysis. In *Proceedings of the FOSS/GRASS users conference* (Vol. 15).

Rju, R., & Kumar, T. M. (2019). Trend Analysis of Area Production and Productivity of Sugarcane in India. Agro-Economist, 6(1), 7-13. https://doi.org/10.30954/2394-8159.01.2019.2

Saini, U. P., Sachan, S. K., Pratap, A., Singh, B., & Kumar, K. (2015). Insect pests associated with basmati rice in western plain zone of Uttar Pradesh, India. Plant Archives, 15(2), 775-777.

Sati, V. P. (2020). Himalaya on the Threshold of Change. Springer. https://doi.org/10.1007/978-3-030-14180-6_9

Sharma, R. K., Abidi, N., & Misra, R. K. (2020). Assessment of agricultural sustainability-a study of farmers growing basmati rice under conventional and fair-trade systems in India. International Journal of Sustainable Agricultural Management and Informatics, 6(1), 1-21. https://doi.org/10.1504/IJSAMI.2020.106549

Sharma, R. K., Abidi, N., & Misra, R. K. (2020). Assessment of agricultural sustainability-a study of farmers growing basmati rice under conventional and fair-trade systems in India. *International Journal of Sustainable Agricultural Management and Informatics*, *6*(1), 1-21.

Shivani Azad (2014). Gone grain: Doon Basmati may soon be dead, Times of India. Gone grain: Doon Basmati may soon be dead | Dehradun News - Times of India

Shrestha, J., Kandel, M., Subedi, S., & Shah, K. K. (2020). Role of nutrients in rice (Oryza sativa L.): A review. Agrica, 9(1), 53-62.

Somayajula, V. K. A., Ghai, D., & Kumar, S. (2021, April). Land Use/Land Cover Change Analysis using NDVI, PCA. In 2021 5th International Conference on Computing Methodologies and Communication (ICCMC) (pp. 849-855). IEEE. https://doi.org/10.1109/ICCMC51019.2021.9418025

Yin, S., Wu, W., Zhao, X., Gong, C., Li, X., & Zhang, L. (2020). Understanding spatiotemporal patterns of global forest NPP using a data-driven method based on GEE. *PLoS One*, *15*(3), e0230098.