International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2024: 7.101

Impacts of Climate Change, Land Transformation and Advanced Technologies on Agriculture: A Microlevel Spatio-Temporal and Geo-Statistical Analysis of Four Mandals of Jangaon District in Telangana

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Abstract: ***Agriculture, a vital sector for global food security and economic development, faces unprecedented challenges from climate change, land transformation, and advanced technologies. Rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events are altering the delicate balance of agricultural ecosystems, impacting crop yields, and threatening food security. Simultaneously, land transformation, driven by urbanization, infrastructure development, and changing land - use patterns, is leading to the loss of arable land, soil degradation, and decreased biodiversity. Advanced technologies, such as precision agriculture, drones, and satellite imaging, offer promising solutions to enhance agricultural productivity, efficiency, and sustainability. However, the adoption and impact of these technologies are uneven, with significant disparities between developed and developing countries, and between large - scale and smallholder farmers. This study examines the complex interplay between climate change, land transformation, and advanced technologies on agriculture, highlighting the need for integrated solutions that balance productivity, sustainability, and equity.***

Keywords: Climate change, Land transformation, Advanced technologies, Agriculture, Food security, Sustainability, Equity

1. Introduction

At various stages of human evolution, we always have tried to find or create better prospective and strategies to satisfy the demand of healthy food with sufficiency in our day to day life. From hunting animals to domesticating the livestock, from searching the fruits and nuts to farming on large agricultural fields has enabled human to cope with every hostile and adverse conditions to identify and alleviate the issues on the way of agricultural production and productivity. In course of time, apart from demand of food, agriculture has played a major role in maintaining the economic stability for any particular class or group of employees and moreover for geographical regions from micro to macro level.

Thus, as a matter of fact nearly 49% of the total workforce of India is engaged in agricultural activities at present to fulfil the total demand of food and other agricultural products. This percentage figure was nearly 70% during the colonial period and 50's in the Nation. Only within a span of seven decades the engagement in agricultural activities in the Nation has reduced by 30% of its original size and even the contribution of Agricultural Industry to the GNP has reduced from 58% to 17%. Whereas at the same time, the population increased almost more than 3.35 times and the production of food grains and commercial crops, increased exponentially at higher angle in the first quadrant. Also, it is to be noted that the agricultural landuse has been increased from 41.77% to 48% of the total geographical area of the nation. Whereas the arable land decreased from 63.9% to 52.8%.

It is thereof no doubt that the issue in the quality and quantity of production can critically be debated alongside the Agricultural Economy. Comparing the growth in the size of population for any region with the quantity of production of food crops, keeping the rise of demand at a constant rate of increase, it can be postulated that the production has exceeded the demand. It ends resulting the fall in the price of the agricultural products in the market because of over production and surplus supply hold to the market. This compels the cultivator to go for crop diversification or a shift in agriculture bearing the loss. Sometimes it ends with no agriculture and change in occupation even. Not only this Neo - Classical theory is applied for food crops, but also it is applied for all other crops supplied to the market and produced for export purpose including the commercial crops.

On the other hand, the pressure on the limited available agricultural land also increases because of maximizing the quantity of production. In most cases the fertility of the land gets highly affected and periodically becomes less fertile to infertile. Although the recent advances in the pattern and practices in agriculture by means of using seeds, fertilizers, insecticides and pesticides has supported to keep the pace of production but the quality of both the consumable agricultural products and the land degrades as well. Putting a question mark on the productivity of the land, this leads to another issue of over exploitation of the land resources converting the fertile lands to infertile and later to be used for some other purpose. In most cases the unused agricultural lands remain fallowed for long period and are later converted to built - up lands. When needed, lands from other categories are again forcibly converted to agricultural

lands. In this case there is a possibility of changing the cropping pattern and combination as per the availability of water and assurance of irrigation to the lands. Fertility also is partially considered for a crop selection for these types of converted land categories. Land alteration affects the type of production, quality of production and quantity of production with a changing land values at various times.

It is true that food and climate are the two - major component and driver of life. Taking all other physical and nonphysical factors affecting the variability in agricultural productivity into account, climate comes first into discussion. It contributes two major indicators i. e. Temperature and Rainfall, in context of deviation in crop yielding in course of time and its quantum of variability. Howsoever crop yield is largely affected by regional climatic variations. Indian Agriculture is largely dependent on monsoon and irrigation. India ranks the 1st at global level to practice rainfed agriculture as it meets monsoon in two seasons a year. So, the yielding of crops is most sensitive to the arrival of the monsoons and the amount of precipitation. These two factors decide the variation of temperature in different seasons of a year and vice - versa. Altogether these three are the main agents those affect the quality and quantity of the agricultural production and productivity in the subtropical geography of Indian Sub - continent. The rapid climate change in last 3 - 4 decades has resulted Frequent Droughts, Low Rainfall, Unexpected Arrival of Monsoon and Duration of Rainy Season, often Heavy Rain within shorter intervals, Floods and Rising Temperature. According to Indian Meteorological Department, the average temperature of the country has risen from 3oC to 4oC since last 3 decades. A rise of 1oC/year in average temperature of the country has an unanticipated impact on every regional climate of the country and so on the plant growth and health with agricultural productivity. The impact is higher in case of the Arid and semiarid regions, especially for Deccan Trap of Telangana. A slight variation in arrival of Monsoon and quantity of pouring affects the Agricultural Activities and the Production with a greater impact on the Agronomy. Howsoever, both in short and long run, as it is also dependent on several other factors viz. assured water supply, human labour, soil fertility and fertilizers used, pesticides and insecticides used, quality of the seeds, moisture contain of the soil, technique adopted for yielding etc, the inter relationship of agricultural productivity and climate is very complicated.

From Anthropogenic point of view, Land Alteration, Assurance of Irrigation, Continuous Intensive Agriculture for long period, GM Cropping, Economic Collapse, Economic Inflation, Market Failure, Sudden rise in Demand of Commercial Crops, Occupational Change, Rural - Urban Migration, Improper Implementation of Anti - Poverty Schemes and Policies, Unawareness of Site Specific Crop Management (SSCM) and Precision Agriculture are some of the major causatives of recent trends in agricultural changes. All of these manmade impediments on the way of agricultural development can be man - handled but with a proper Scientific and Socioeconomic analysis with approaches. From Natural point of view, continuous Drought and sudden Heavy Rain for consecutive years but with improper arrival and continuity in duration, Rise in temperature causing crop burn and Ground Water Depletion are the primary reasons for the changes in agriculture.

As a whole, ultimately the Agrarian Economy from the grass root level (from every individual farmer) to the national level gets highly affected and is already affected. Finding the loop holes in the system and the importance of the agricultural indicators are most often found to be justified but succeeded less in posing a grip over the issues to maintain the balance in a sustainable way.

In this study an attempt is made to address the level and intensity of pressure of various agricultural indicators for such an agriculturally rich (Biotic GM Crop – Cotton farming) District although located on Deccan Trap of Telangana in a semiarid agroclimatic region. Vast diversification of crops has attracted the attention of analysing the quality and quantity of production in the District affecting the Agrarian Economy at micro level. The Demand - Supply, Demand - Cost, Supply - Cost and Demand - Cost, Perfect Competition of the market entrepreneurship is to be studied to evaluate the Status of Agriculture and Socioeconomic condition of the rural livelihood.

Agriculture is not only a source of food or economy but also it has many Socio - cultural empathies associated with which ultimately affects the standard of life of rural economies.

2. Review of the Literature

Bhawani P., Chakravarthy V., P. S. Roy, P. K. Joshi and Chandrasekhar K (2016): have attempted to evaluate the Long - term agricultural performance and climate variability for drought assessment in Telangana and Andhra Pradesh. They highlighted the long - term spatiotemporal variation of precipitation and residual moisture are the determining factors of the crop area, growth and stress. Rainfall and water availability are the main drivers of agricultural performance. Most of Telangana and Andhra receives the highest rainfall during the summer monsoon, which also has an impact on the winter and summer crops. To assess the vulnerability of the region, it is essential to use the satellite - derived indices (NDVI), the cropped area and its fluctuation, the preceding year's seasonal precipitation and the sources of irrigation.

A V. Shashikala (2016): have done in detailed research about the impact of climate change on agricultural productivity in selected mandals of Nalgonda and Khammam Districts. In their research they corelated the effect of two major agricultural indicators i. e. Rainfall and Temperature on all individual major crops of the District region and tried to justified as apart from climatic variation other indicators like Crop investment has played the major role in Crop Diversification from Multiple crop to Mono Crops. Further they used Ordinary Least Square Method to understand the contribution of the crops to the GDP and the economic importance of the crops produced within the region.

Vijay Paul Sharma (2015): has studied the dynamics of Land Use Competition in India and found that the diversion of

agricultural land is almost unavoidable phenomenon because of growing population, urbanization, industrialization and infrastructure development. However, unplanned and unrestricted diversion of agricultural land for non - agricultural purposes has significant adverse impact on agricultural production and therefore a threat to food security and livelihoods. The loss of prime agricultural land to non - agricultural uses is intensifying in the country but varied across different states in which Andhra Pradesh and Telangana showed the higher rate of increase in the list during the last two decades. Underutilization of agricultural land as indicated by share of net sown area in total arable land is an issue and concentrated in Andhra Pradesh and Telangana, the hilly states and states having a large number of tribal areas. The low utilization of arable land in most of these states is primarily due to lack of irrigation facilities. The high utilization of agricultural land.

Brajesh Jha (2013): has analyzed the Strategies, Trends and Status of Employment, Wages and Agricultural Productivity in India. As he concluded that Labor productivity in agriculture has increased subsequently declining the agricultural employment in the 90s. The real wages for agricultural workers has increased consistently during the 90s, though certain indices of agricultural productivity have not increased significantly. From a regression analysis he explained the factors behind real wages in agriculture shows that the effect of labor productivity on real wage has decreased while that of the labor - land ratio has increased during a period of 16 years from 1983 to 1999. In other words, in agriculture the labor market influence of demand decreases while that of supply has increased. Thus, the increase of wage incommensurate with the increase in agricultural productivity cannot be sustained for long.

M. Mannion & Stephen Morse (2013): have done a global level study on GM crops and Agronomic, Environmental and Socioeconomic impacts. The review shows GM crops are risky and advantageous both. The benefits outweigh the risks so that they should be considered a valuable asset in the fight to increase global food production. The gains are particularly noteworthy in relation to agronomic and environmental considerations; since their commercial planting in 1996 they have made a positive contribution to arable productivity in all regions which grow them and to both commercial and subsistent farmers. However, GM crop may be accompanied by a number of other innovations such as improved use of fertilizer or water management for which it is not generally possible to account quantitatively. Socio - economic benefits are less clear cut than agronomic and environmental benefits, especially in relation to debt issues; it is unclear at present what effects it may have had on society and whether it is worse for farmers producing GM crops than those producing conventional varieties.

Manickam Valli, Radhika R. and Krishna Iyyanki V. Murali (2012): have attempted to study the impact of Climate variables on crop productivity in Warangal District of Andhra Pradesh (present Telangana). They concluded that continuous droughts and unassured rainfall with irrigation has affected the soil health to its extreme level so that the diversification of crops and the gross production has declined to its maximum extent. However, the yield of cash crops has somehow managed in balancing the economic stability of some Big land holders. This also has shown a negative impact on the SDP with respect to the Food Crop production.

Assumption and Hypothesis:
As observed, the rate of population growth is lower than the rate of increase in production of Agricultural goods and commodities. But the contribution of Agricultural Sector to GDP is continuously declining. Investment on Agricultural sector has declined but Production has increased with mono cropping and diversification from Food to Cash Crops. Economic loss and mismanaged Supply of inputs and outputs has affected the production, supply, export interval and value with quantity and retail cost leading to compel the cultivators to change the crop combinations and the cropping pattern. Alteration of Land with improper evaluation of the land value has tempted the farmers either to stop the agricultural activity during the current session or to restart on the altered land parcels with a crop variation without proper knowledge, skill and prior information about the future consequences. Where at national level the production of cereals has increased to more than 20 times with an increase of pulses and millets to 5 times, but it seems the ratio is not parallel at microlevel study. Especially in case of Jangaon District it has been observed the patterns and practices of agriculture has been inclining more towards cash crops than producing food crops in course of time since last 3 decades.

3. Objectives of the Research

1) To Study the shift of Climate Anomaly of the region with respect to the real - time weather monitoring for the recent years along with the soil health and its correlation with the traditional and existing Cropping Pattern.
2) To make a comparison of Landuse and Land cover of the Study area for last 30 years from Spatial, Resource and Economic point of view to identify the impact on agricultural lands.
3) To understand the intensity of pressure of various socioeconomic and policy indicators on agricultural practice other than the landuse change and Climate change.
4) To identify the vulnerable crops with production risks and marketing risks and, addressing the key causatives for each identified crop being diversified for its production in quantity.
5) To suggest the possible measures to mitigate the risk factors for such dynamism in cropping with less exploitation of the resources in a balanced economic manner.

Study Area
Telangana is one of the key contributing state to the GDP in terms of agricultural outputs in India. Within these four agroclimatic zones, i. e. North Telangana Zone, Central Telangana Zone, High Altitude Zone and Southern Telangana Zone, Jangaon District fall under Central Telangana zone. All 13 mandals of the District has been taken for the evaluation and assessment of the purpose of the research.

Jangaon District receives nearly 960mm of normal annual rainfall. Rainfall increases from the South - west to North - east region varying from 690mm to 1060mm during the peak period of the rainy season during the month of August and September. The South - west monsoon contributes the maximum percentage of rainfall that is nearly 80% of the annual total. Generally, the summer season of the District continues from March to end of June. During this season temperature range varies between 30°C and 42°C. Average temperature during this season is about 32°C. The Winter continues from End - October to mid - February. During this season temperature range varies between 14°C and 28°C. Average temperature during this season is about 20°C. During Monsoon (from June to end of September) the weather remains hot and humid. Over all the climate of the district is Semi - arid.

Paddy, Jowar, Maize, Pulses, Sugarcane, Cotton, Turmeric, Chilies Castor, and Sunflower are the primary crops grown in Central Telangana Zone. This research is mainly focused on the impact of climate change on the production of Rice, Jowar, Maize and Chilly in the four selected mandals of the district.

Data collection:

- SOI Toposheets on 1: 50000 scale are obtained from SOI distributed through online portal.
- Multi - seasonal Landsat 5 and 8 scenes are obtained from the USGS earth explorer website in every 10 years interval starting from 2000 till 2020.
- Soil type data is collected from TRAC, Hyderabad.
- Administrative boundary vectors are collected from Telangana Open Data portal and village Boundaries are obtained from LGD, India.
- Census data for the period 2001 and 2011 are obtained from the District Census Handbooks.
- Agricultural statistics is obtained from the District Statistical Handbooks of Warangal and Nalgonda districts for the years 2001 and 2011 and 2020 for Jangaon district from DES, Hyderabad as well as CPO - Jangaon also from the Directorate of Horticulture, TS.
- Climate data is obtained from IMD, Hyderabad.
- DSM raster data is obtained from ALOS - PALSAR ASTER.
- Groundwater data was collected from CGWB, Bandlaguda, Hyderabad.
- Irrigation data is obtained from the Irrigation and CAD wings, Hyderabad.
- Production, Supply and Price of the selected crops data in the study area is collected from the Directorate of Agricultural Marketing, Hyderabad.
- The primary data will be collected from the sample locations through structured questionnaires which will be interviewed to the agricultural marketers as well as the cultivators.

4. Methodology

1) Base map for landuse and land cover studies have to be prepared from, 1980 - 85 SOI toposheets on 1: 25000 scale.
2) For temporal Analysis and comparison of the Earlier LULC, Satellite Scenes of EO Hyperion HySI for the year 2005 and Sentinel - 2 HySI for the year 2017 have to be Classified and statistical calculation of the change detection will be carried out to find out the vulnerable agricultural lands.
3) Soil maps and various Crop Combination, Cropping Pattern, Cropping Intensity, Crop Diversification maps will further be prepared for overlay analysis of the changes over the period of 30 years after the data collected from the concerned mandal level offices and Directorate of Agriculture, Directorate of Economics and Statistics.
4) Climatic Data from Indian Meteorological Department (IMD), Irrigation Data from State Irrigation and cad Wings, Ground Water data from CGWB, Socioeconomic Data from Mandal Revenue Offices (MRO), Directorate of Economics and Statistics and Directorate of Agriculture for a period of 30 years (1985 - 2017) will be collected and incorporated to the Maps.
5) IBM SPSS and MS Excel were used for correlating several climatic factors. Establishing a correlation between year wise annual rainfall and crop yielded in tons and the variance of year wise percentage deviation of the rainfall, the above four mandals were found to be most affected by climate change in agricultural sector. Ordinary Least Square (OLS) model was used to link the GDP and the Prices of the agricultural products to estimate R2 Values of the major crops. Applying neoclassical Theory, the Agronomy on behalf of its demand and supply will be analyzed to accurately distinguish the threatened crops and finally to enlist the causes and consequences of recent trends of agriculture.
6) Using questionnaire Field Survey will be carried out for individuals' views and expectations to be incorporated to the DSS for final output.

5. Results

The impacts of climate change, land transformation, and advanced technologies on agriculture in Jangaon District are multifaceted.

Climate Change Impacts

- Rising temperatures and altered precipitation patterns affect crop yields and food security.
- Increased frequency of extreme weather events like droughts and floods stresses water resources and soil health [1].
- Warmer temperatures exacerbate pest infestations, further stressing crops.

Land Transformation Impacts

- Urbanization, infrastructure development, and changing land - use patterns lead to loss of arable land, soil degradation, and decreased biodiversity [2].
- Land inequality, poverty, and food insecurity are exacerbated by land transformation

Advanced Technologies

- Climate - resilient crop varieties, efficient irrigation systems, and precision farming tools enhance agricultural productivity and sustainability.
- Space technology, AI, and genetic engineering can help develop resilient crops, monitor crop health, and

optimize yields[3].

6. Recommendations

- Implement climate - smart agriculture practices, such as crop rotation, conservation tillage, and organic farming.
- Promote sustainable water management, soil conservation, and agroforestry practices.
- Enhance institutional capacity, international cooperation, and funding to support climate adaptation efforts.

Tentative Chaptering Scheme

1) Chapter – I: The first chapter gives a brief introduction on the background of the study, the significance of the research and the study area. This chapter mainly highlights the statement of the problem which justifies the sensitivity of the addressed issue. It also underlines the primary goals, hypothetic outcomes, main objectives and finally notes the reviews on the previous similar work done by other researchers.
2) Chapter – II: The second chapter describes the various sources of data obtained and the techniques adopted for the successful completion of the research. This is basically the research design chapter which elaborately describes the detailed methods, approaches, research gaps and limits and the dimension of the research.
3) Chapter – III: The third chapter explains the physiographic condition of the study area which includes the topography such as relief, slope and aspect, hydrology such as drainage and groundwater, climate such as temperature and rainfall, demography such as population and density, agricultural labor force, distribution of soil - types etc.
4) Chapter – IV: The fourth chapter gives detailed account of the land utilization statistics and the satellite driven land cover - landuse change. This chapter primarily focuses on investigating the agricultural landuse change that has occurred in the district in every decadal interval.
5) Chapter – V: The fifth chapter elucidates the patterns and practices of agriculture in the study area which also incorporates the linkage and correlation between the farmers point of view. This is the most important chapter which involves in all statistical computations conducted for achieving the goals of the research and draw the conclusions.
6) Chapter – VI: Finally in the last chapter, the finding of the analysis conducted in the fourth and fifth chapter will be postulated where the hypothesis will be tested. Based on the significance test, the conclusions are will be drawn in this chapter and at the end the necessary recommendations will be made.

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