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Climate change and cropping pattern in Keonjhar District of Odisha, India

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Abstract Climate change is one of the most pressing challenges facing humanity and the natural environment in the 21st century. The agriculture sector is particularly vulnerable to climate change, as it depends on the availability and quality of natural resources, such as land, water, and soil. Climate change can affect the cropping pattern in various ways, such as altering the length and timing of the growing season, changing the water availability and quality, increasing the frequency and intensity of pests and diseases, and creating new opportunities and challenges for crop diversification. The agriculture sector in the Keonjhar district of India has been experiencing changes in its cropping pattern. This study investigates the key drivers for changing cropping patterns in the district. Secondary data was collected from 2011 to 2019 on the areas under crops and production of agricultural and horticultural crops grown in Keonjhar. For primary data, the interview method has been adopted with a sample of 327 marginal and small farmers from two villages in the district. The study revealed positive changes in the area allocated for paddy and mango, but negative changes in the area allocated for maize, mung (Yellow Lentil), biri (White Lentil). Climate change, market status, land ownership, education, the decline in yield, and the production of crops were the main drivers of the changes in crop patterns during the past few decades. This research proposes agricultural intensification and policy direction to promote the cultivation of paddy, maize, and mango trees to sustain livelihoods in the Keonjhar district.

Keywords: agriculture, climate change, cropping pattern, horticulture, mann-kendal test

1. Introduction

Climate change is one of the most pressing challenges facing humanity and the natural environment in the 21st century. It refers to the long-term changes in the average weather conditions of the Earth, such as temperature, precipitation, wind patterns, and extreme events (NASA, 2021). Climate change can significantly impact various sectors of human activity, such as agriculture, water resources, health, energy, and biodiversity. Among these, agriculture is particularly vulnerable to climate change, as it depends on the availability and quality of natural resources, such as land, water, and soil (Singh et al., 2020). It can affect the cropping pattern in various ways, such as altering the length and timing of the growing season, changing the water availability and quality, increasing the frequency and intensity of pests and diseases, and creating new opportunities and challenges for crop diversification (Duku et al., 2018). The effects of climate change on the cropping pattern can vary across regions, crops, and farming systems, depending on the local context and the adaptive capacity of the farmers (Duku et al., 2018). Climate change can also have spatial and temporal heterogeneity in its impacts on the cropping pattern, depending on the regional and local variability of climatic factors and the socio-economic and institutional factors that influence farmers' decisions. For example, some regions may experience more frequent and severe droughts or floods, while others may have more stable or favorable conditions. Some farmers may have more access to information, technology, and resources to cope with climate change, while others may have less (Feng et al., 2023). Climate change can also have cumulative and long-term effects on the cropping pattern, depending on the feedback loops and interactions between biophysical and human systems. For example, climate change may alter the soil organic matter, nutrient cycling, and biodiversity, which may in turn affect crop productivity and resilience. Climate change may also affect the food security, income, and livelihood of the farmers and consumers, which may in turn affect the demand and supply of agricultural products (Wu et al., 2023).

On the other hand, a crop pattern is defined as the proportion of area devoted to various crops throughout a specific period (Misra & Puri, 1984). It is a dynamic term that encompasses a variety of cropping operations on agricultural lands

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(crop systems). It is therefore evident that the pattern of crops is influenced by fluctuations in the weather, as has been mentioned before. Besides, it also depends on the socio-economic factors, the situation in terms of food security, government subsidies to farmers, and market demand.

In East-Asian and Latin American countries' cropping patterns change from traditional crops to cash crops (due to their high value), which helps to generate income, reduce poverty, promote employment, and increase agricultural exports. In the Himalayas, it has been noticed that many farmers have abandoned traditional crops in favour of cash crops during the past few decades and that crop productivity has decreased by 30% on gross cropped land (Regmi, 2007), in contrast, rice production has increased in South Asia (IRRI, 1995; Ryan & Spencer, 2001). A major change in the pattern of crops in India has occurred since the Green Revolution, resulting in rice, wheat, and pulses grain. Mountainous areas were greatly affected by the green revolution, and rice has become a basic food that is grown in wet areas by over 60% of the area under cultivation.

The impact of climate change on the yields of major crops across India shows that there is a significant rise in the monthly temperature mean specifically in post-rainy season and the minimum temperature increase is beneficial for crop yield but not as much as to cover the adverse effects of the increase in maximum temperature (Birthal et al., 2014). More recently a study that included the effect of infrastructural factors and techniques of production along with climate change, found that further development of infrastructure in this sector needs to be opted as fertilizer use (Pani et al., 2021), road connectivity and market along with storage facilities was found the major drivers of agrarian transition (Paria et al., 2022). Another study, which included the study of location and the management of crops along with climate change to protect the climate scenario and impact on major crops (Ferdushi et al., 2023), found out that irrigated rice and potato in the north-eastern region, rice in the eastern coastal region and coconut projection in the western ghats will have a favorable effect. Whereas, irrigated maize, wheat, and mustard in the north-eastern and western ghat region may be affected adversely. This implies how climate change can affect different crops differently and variety and altered agronomy need to be adopted (Kumar, 2011). A study completely focused on rice productivity because of climate change in Kerala, India that CO2 concentration enhancement can lead to an increase in the yield of paddy due to the fertilization effect. The rainfall, on the other hand, has a positive effect on rice yield and even the decrease in rainfall happens to affect the yield negatively (Van Dat & Hasan, 2019). The temperature analysis showed that an increase in temperature up to 5 degrees Celsius can affect the yield negatively (Saseendran et al., 2000).

A review of literature specifically for horticulture has been done to find the effect of climate change on horticulture crops (Saqib et al., 2022; Jha & Gupta, 2021). In a review paper, it was found that climate-smart agricultural or horticulture adoption can be favorable for production (Kifle et al., 2022), (Jägermeyr et al., 2021). Location diversification can reduce the adverse effect of global warming and development in terms of market (Damodar et al., 2021), and infrastructure can sustain and even favorably affect horticulture crop production (Malhotra, 2017). Another study found a data gap especially for natural resources, because of which the analysis couldn't be done significantly. The need for relevant data is evident for scientific analysis in terms of horticulture crops (Bhattacharyya et al., 2021).

In this context, the paper aims to ascertain the important factors responsible for changing agriculture and cropping patterns; and analyze the implications of climate change, along with other factors, on cropping patterns.

2. Materials and Methods

2.1. Study Area

Keonjhar district of Odisha in India is a landlocked district in northern Odisha that is bordered on all sides by other districts: Dhenkanal and Sundargarh districts on the west; Mayurbhanj and Bhadrak districts on the east; West Singhbhum district of Jharkhand state on the north; and Jajpur district on the south. With its prevailing climatic conditions and soil types, the Keonjhar district is an ideal location for growing agricultural and horticultural crops (Figure 1). The district receives an average annual rainfall of 1910.1 mm, with the major part of that precipitation (80%) falling from June to September. The summer is also marked by high humidity, which begins in March and peaks in May at a temperature of about 38 degrees Celsius.

The district is coming under the Scheduled-V areas of the Constitution of India (Govt. of India, n.d.). Keonjhar district covers a total area of 830 thousand hectares, of which 298 thousand hectares are cultivated and 310 thousand hectares are forest. In addition, a total of 41.2% of its soil is red. The net sown area is 290 thousand hectares with 440 thousand hectares as cross cross-cropped area (District Statistical Hand Book Keonjhar, 2020). For crops, rice and maize are the most important, while mango ranks as the most important horticultural crop. Based on the Census (2011), 86% of the population lived in rural areas. In the Spring and Kharif (Wet) seasons, approximately 80% of the labour force earns their income through the cultivation of rice, maize, and mangoes. There are two irrigation projects in the area: first is the 'Kanpur Irrigation Project' and the second is the 'Anandpur Barrage Project', which is under construction.

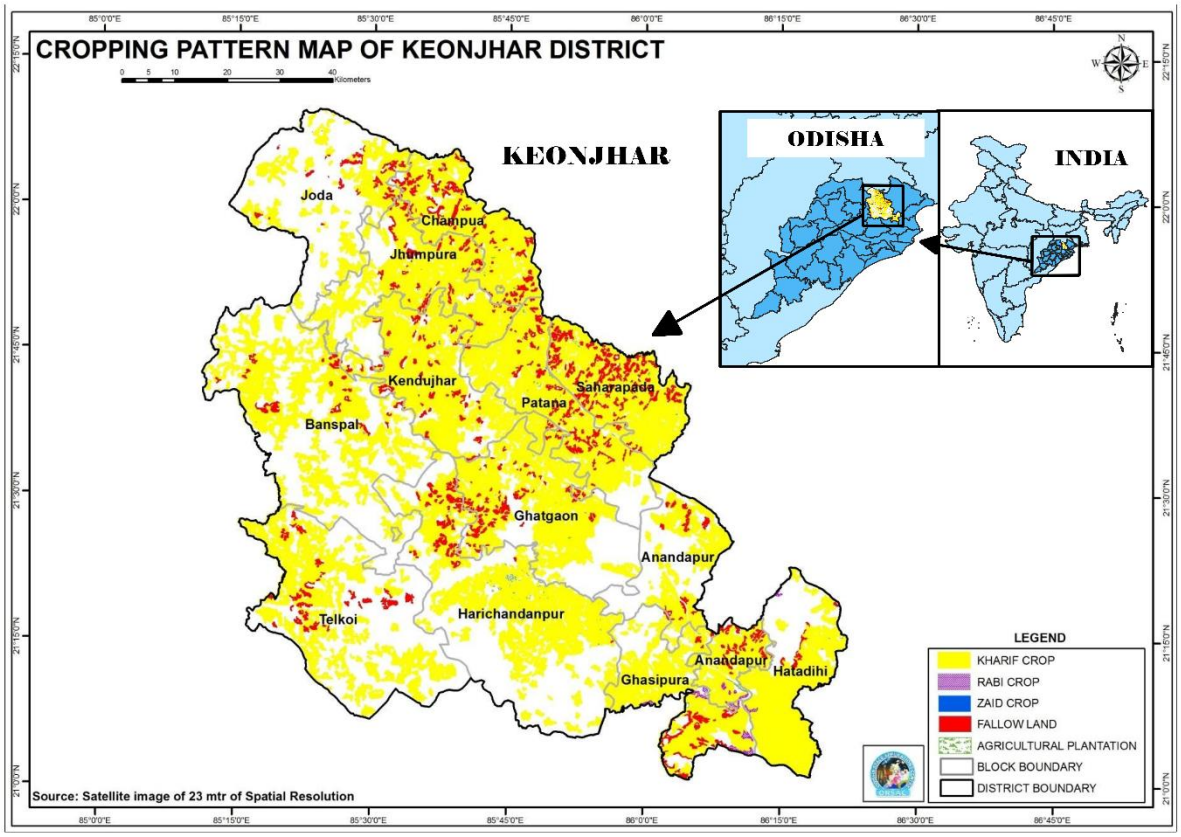

Figure 1 Cropping pattern map of Keonjhar district.
Source: Odisha Space Applications Centre, 2016.

2.2. Data Sources

The study used both quantitative and qualitative data. The secondary data were collected from the agricultural statistics of Odisha from 2011-12 to 2018-19 on agricultural and horticultural crops growing in the Keonjhar district of Odisha, India including cultivated area, production, yield, and appropriate statistical analysis was done to indicate the pattern in the data. Additionally, climatic data were collected from previous agricultural statistics of the Government of Odisha. Primary data was collected from 327 sample marginal and small farmers in two villages in Keonjhar district; one from Joda block (mining area) and another from Banspal block (non-mining area). The sample households were selected based on simple random sampling. The interview method with a structured interview schedule was followed for primary data collection. The important primary data collected include land ownership, crop wise yield, area under different crops, occupation and changing market status. The qualitative data include the information collected through discussion with different stakeholders including village leaders and local vel government functionaries. Data was analyzed by using descriptive statistics, 'Mann-Kendal Test' (Libiseller & Grimvall, 2002), 'Sen's Slope Estimator' (Gocic & Trajkovic, 2013), and the linear regression model. Examinations for identifying statistically significant trends in climatological time series can be categorized into parametric and non-parametric methods. Non-parametric trend tests simply need that the data be independent; parametric trend tests demand that the data be both independent and normally distributed. This paper uses the two non-parametric techniques (Sen's slope estimator and Mann-Kendall) to ascertain the trends in the meteorological variables.

3. Results and Discussion

This part of the paper is segregated into two sections: (i) major drivers of changing agriculture and cropping patterns, and (ii) implications of climate change on cropping patterns.

3.1. Major Drivers of Changing Agriculture and Cropping Patterns

3.1.1. Climate Variability and Change

Based on the secondary data collected from 2014 to 2018, Table 1 shows the fluctuations in rainfall and temperature over five years. 'Mann-Kendall' and 'Sen's Slope Estimator' were used to evaluate rainfall data for 30 years (from 1989 to 2018) to determine the trend. Table 2 shows the monthly and seasonal data for the Z and Q values. Rainfall has been

trending downward significantly, especially in June. 'Sen's Slop Test' was used to determine the magnitude of rainfall trends for all months, and it revealed that June had the lowest rainfall slope (-3.247 mm). The onset of monsoon used to happen in this month.

Table 1 Climate variability and change (five years).

Year	Minimum Temperature (°C)	Minimum Rainfall (mm)	Maximum Temperature (°C)	Maximum Rainfall (mm)	Mean Temperature (°C)	Mean Rainfall (mm)	Std. Temperature (°C)	Std. Rainfall (mm)
2014	10.1	0.1	38.2	427.7	24.15	133.96	19.87	149.22
2015	13.1	0.2	38.3	319.2	25.7	84.125	17.82	98.15
2016	12	1.7	41	348.5	26.5	110.11	20.51	116.42
2017	11.4	0.1	39.3	320.5	25.3	111.66	19.79	106.05
2018	9.4	0.2	36	375.1	22.7	138.8	18.81	147.63

Source: Odisha Agriculture Statistics, different years from 2014-15 to 2018-19, Department of Agriculture & Farmers' Empowerment, Government of Odisha, Bhubaneswar.

Table 2 Trend results of average rainfall during thirty years (from 1989 to 2018).

Time series	Test-Z	Sig	Sen's Slope (Q)
January	0.56	-	0
February	0.36	-	0
March	0.86	-	0.162
April	0.25	-	0.192
May	0.14	-	0.229
June	-1.96	*	-3.247
July	1.57	-	2.812
August	-0.64	-	-1.436
September	0.46	-	0.7
October	0.14	-	0.112
November	-0.82	-	-0.09
December	1.6	-	0
Annual	0.32	-	2.282
Summer	0.79	-	0.596
Pre-monsoon	0.32	-	0.469
Monsoon	-0.04	-	-0.74
Post-monsoon	0.32	-	0.566

* at 0.05 level significance

Source: Special Relief Commissioner, Government of Odisha, Bhubaneswar.

3.1.2. Climate Change

Climate change and its fluctuations have contributed to changing agricultural patterns and a decrease in the yields of major crops of both horticulture and agriculture crops. The cultivated area of these crops has continued to decline over time due to the scarcity of rainfall during the growing season, as well as the occurrence of floods. Moreover, climate change (rising temperatures and changing weather patterns) was also found to be one of the important reasons for changes in agriculture and cropping patterns (Table 3).

Table 3 Important factors responsible for changes in agriculture and cropping pattern (n=327 with a cumulative frequency of 1631).

Variables	Frequency	%
Climate change	310	94.8
Land ownership	305	93.27
Low yield of crops	290	88.69
Occupational change	260	79.51
Changing market status	251	76.76
Education	215	65.75

Source: Field survey, 2022.

3.1.3. Changing Market Status

The significant increase in the price of mango in neighboring areas has led farmers to prefer its cultivation to a great extent. This, in turn, may impact the mango market in the Keonjhar district, where the price of mango is currently low as compared to that in neighboring areas. The transportation facilities are considered to be an important factor that affects the marketing of crops, especially in rural areas of Keonjhar. Consequently, the high transportation costs resulting from the aforementioned price difference (changing market status) may affect the net seasonal profit (Table 3).

3.1.4. Land Ownership and Technical Tools.

The effective cultivation of agricultural lands in Keonjhar may be hindered by the prevailing system of land ownership. This is because the majority of farmers in the area work as wage laborers, resulting in low agricultural yields. Additionally, these farmers are unable to afford the expensive fertilizers and technical equipment that are necessary to enhance productivity. As a result, the marginal and small farmers face disproportionately high production costs (Table 3).

3.1.5. Low Yield of Crops

Soil erosion, fragility, and declining productivity over time represent significant factors that have contributed to the decline in agricultural production and a shift in crop patterns. Some of the agricultural or horticultural crops in Keonjhar have extremely low yields, which are inadequate to meet the demands of the market and the needs of the growing population (Table 3).

3.1.6. Occupational Change

In the Keonjhar district, a significant factor contributing to the decline in production is the trend among young people to change their professions; as approximately 60% of young people are shifting from agriculture to the service sector. This shift is driven by a belief that agriculture is ineffective and the output is useless (Table 3).

3.1.7. Education

According to Census (2011), education in Keonjhar district was on the rise, as the literacy rate increased in the area. Educational institutions are also growing and expanding. Consequently, the output from crop cultivation provides fewer employment opportunities compared to the education sector. Educated rural youth prefer to work in the education sector rather than engage in farming (Table 3).

3.2. Implications of climate change on cropping pattern

This section describes how agriculture and harvesting patterns have changed in Keonijhar, shifting from the traditional production of mung (yellow lentil) and biri (white lentil) to horticulture crops like mango.

3.2.1. Area and Production of Agricultural Crops

An analysis of secondary data was conducted on the crops (area and production) grown in Keonijhar, Odisha. Based on the agricultural statistics data available at the time of the study, the period from 2011-12 to 2018-19 has been studied. From the gross cropped area, we calculated the percentage of crop area. The cultivated area in 2011-12 was 394.63 thousand hectares, with paddy (rice) constituting 43.45% of the total. In the Kharif (wet) season, pulses and oilseeds account for 68.32% and 9.12% respectively, making it a higher percentage than in the rabi (dry) season. The percentage of area under maize, mung, and biri has decreased from 24.57, 12.70, and 18.06 thousand hectares in 2011-12 to 23.13, 10.63, and 16.69 thousand hectares in 2018-19 (Figure 2).

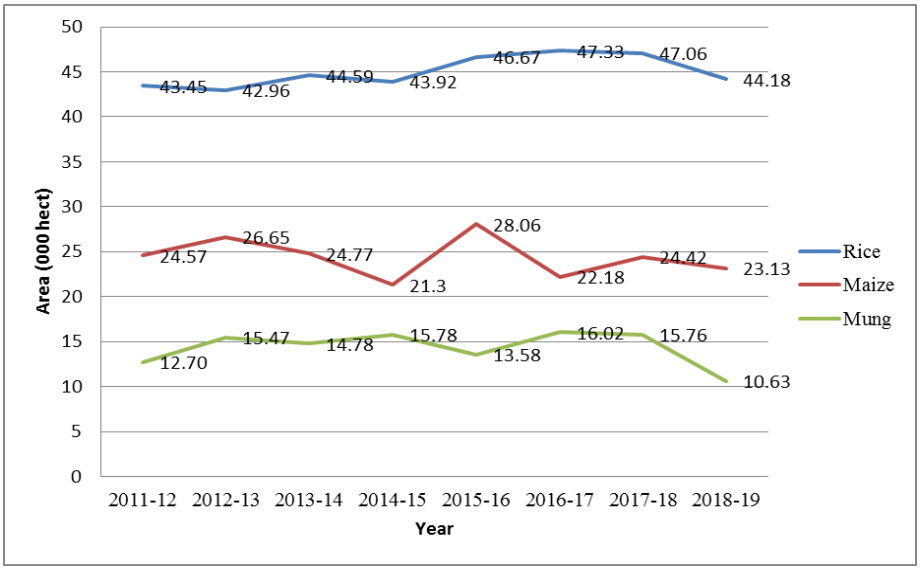

Figure 2 Agriculture crops area as a percentage of gross cropped area in Keonjhar district.

Source: Odisha Agriculture Statistics, different years from 2011-12 to 2018-19, Department of Agriculture & Farmers' Empowerment, Government of Odisha, Bhubaneswar.

In terms of production, data was also gathered from 2011-12 to 2018-19. It was observed that paddy output increased from 428.28 thousand MT in 2011-12 to 556.57 thousand MTs in 2018-19. Besides, maize production has increased from 35.18 thousand MT in 2011-12 to 67.94 thousand MT in 2018-19, whereas mung and biri production show a very insignificant increase from 4.74 and 7.47 thousand MT in 2011-12 to 5.24 and 8 thousand MT in 2018-19 respectively (Table 4).

Table 4 Production of agriculture crops in Keonjhar district from 2011-12 to 2018-19 (*'000 MT*).

Production	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
Paddy	428.28	430.29	413.09	625.38	313.6	639.77	598.55	556.57
Maize	35.18	46.88	59.91	51.5	69.12	65.54	69.4	67.94
Mung (Yellow Lentil)	4.74	7.92	7.32	7.88	6.58	7.2	7.72	5.24
Biri (White Lentil)	7.47	10.17	8.7	10.51	7.55	10.49	9.9	8

Source: Odisha Agriculture Statistics, different years from 2011-12 to 2018-19, Department of Agriculture & Farmers' Empowerment, Government of Odisha, Bhubaneswar.

3.2.2. Area of Horticultural Crops

Keonijhar is home to a variety of horticultural crops, the most significant of which is the mango crop. Data on the production and area were collected from 2011-12 to 2018-19. It revealed an increase in the area of mango from 10.29 thousand hectares in 2011-12 to 10.5 thousand hectares in 2018-19 (Figure 3). In terms of horticultural crops, Keonjhar's mango crop accounts for a sizable portion. Mango cultivation accounts for 70.28% of the total area, with the remaining proportion being made up of other types of crops (guava, citrus, litchi, sapota, banana, papaya, pineapple, pomegranate, and others).

3.2.3. Change in Agriculture and Cropping Pattern

According to the data, the agricultural system in the Keonijhar district has changed from traditional farming to stable farming. As certain planted crops in the area are being reduced, other resilient horticultural crops take their place (Figure 4).

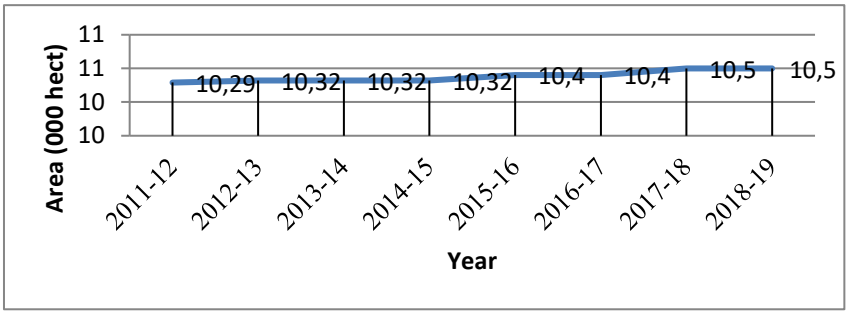

Figure 3 Area in (000 hect) of horticulture crop (mango) in Keonjhar district from 2011-12 to 2018-19.
Source: Odisha Agriculture Statistics, different years from 2011-12 to 2018-19, Department of Agriculture & Farmers' Empowerment, Government of Odisha, Bhubaneswar.

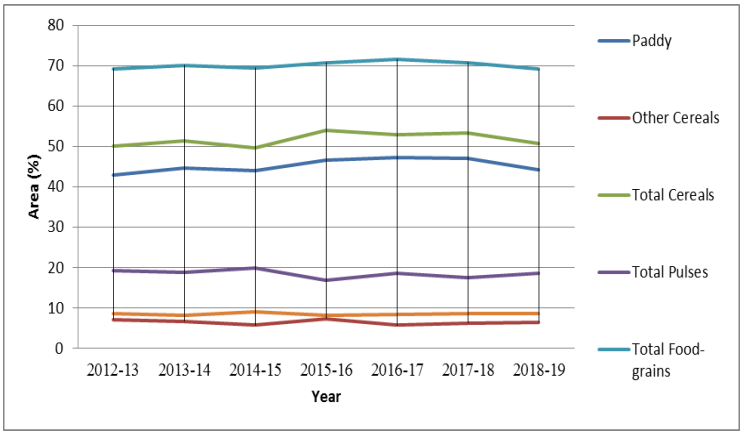

Figure 4 Percentage of agriculture crops area out of the gross cropped area in Keonjhar district from 2012-13 to 2018-19.
Source: Odisha Agriculture Statistics, different years from 2012-13 to 2018-19, Department of Agriculture & Farmers' Empowerment, Government of Odisha, Bhubaneswar.

3.2.4. Changes in Agricultural Crops

As shown in Table 5, linear regression was used to estimate the cultivated area of the main crops during the period 2011–2018. It is shown that the cultivated area and production of paddy have increased with the regression coefficients 0.43 and 25.09 respectively. Despite a decrease in the cultivated area of maize, its production increased with a regression coefficient of -0.26 and 4.48 respectively. The cultivated area for both mung and biri crops decreased with regression coefficients of -0.03 and -0.14 respectively.

Table 5 Crop-wise change in area, production, and yield of agriculture crops in Keonjhar district from 2011-12 to 2018-19.

Crops	Change in area (Linear regression)	Change in production (Linear regression)
Paddy	y = 0.4361x + 43.056	y = 25.09x + 387.78
Maize	y = -0.2648x + 25.576	y = 4.4813x + 38.018
Mung	y = -0.0312x + 19.528	y = 0.0568x + 8.8432
Biri	y = -0.1371x + 14.957	y = 0.01x + 6.78

Source: Odisha Agriculture Statistics, different years from 2011-12 to 2018-19, Department of Agriculture & Farmers' Empowerment, Government of Odisha, Bhubaneswar.

3.2.5. Changes in Horticultural Crops

Being one of the important horticultural crops in Keonijhar, the mango crop had its area analyzed. A rise was noted in the crop area from 2011-12 to 2018-19; according to the linear regression equation y = 0.032x + 10.237, meaning that the linear regression coefficient is the positive direction of 0.032 (Table 5). This increase is due to the mango crop area for several reasons that were already discussed in an earlier section.

To comprehend the nature and causes of changes in agriculture and crop patterns, as mentioned earlier, the survey results show that some of the most significant factors influencing agricultural patterns are climate change and its variability, low crop yields, career change, market change, and education which has been discussed in detail in the above section.

4. Conclusions

This paper reveals a change in agriculture and crop patterns in the Keonjhar district, characterized by a decrease in the cultivated area and crop production. Despite their lower proportion, it is noteworthy that an increase in the area of stable horticultural crops has been observed. This change in crop patterns can be attributed to a range of factors or motivations, including climate change, fluctuations in market status, land ownership, low yield of crops, occupational change, and education. Farmers have changed their agricultural practices and crop patterns as a result of their inability to adapt to emerging changes, which have led to price volatility, food insecurity, and malnutrition. The region requires a comprehensive policy to address the implementation and development of crops with priority given to the cultivation of rice and horticultural crops such as mango. The development of climate-resistant crop varieties is essential to enhance food security and ensure sustainable agriculture. The state government may intensify its support for marginal and small farmers in this regard.

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Ethical considerations

Not applicable.

Conflict of Interest

The authors of this manuscript declare that they have no conflicts of interest in accordance with the ethical standards and guidelines for publication.

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