Climate change and agriculture in a mining context of Odisha, India

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Abstract The paper investigates the changing agricultural patterns of crops in the state of Odisha, especially in the Sundargarh district over 15 years. It addresses the question, of how climate change affects agriculture particularly the cropping patterns in the mining context of Odisha, India. The changes in cropping patterns directly impact the livelihoods of the population, who depend on agriculture. The study covered the major crops in the district from 2004-05 to the 2018-19 seasons by utilizing secondary data and intersecting it with primary data gathered from farmers in the district. The data was analyzed using descriptive methodology and primary data was collected through the Focused Group Discussions (FGDs) tool in the Hemgiri Block of the Sundargarh district. The results revealed several factors that directly contributed to changes in cropping patterns, including climate change, government projects, mining activities, and market dynamics. A decline in paddy crop area was observed with a shift toward the cultivation of pulses, oilseeds, and fruits such as mango and cashew. Overall, these findings indicate a significant change in agricultural preferences and a shift among farmers toward high-value economic crops.

Keywords: agriculture, cropping patterns, climate change, mining

1. Introduction

Policy leadership assumes a pivotal role in the successful implementation of development strategies, particularly in achieving economic and social transformation. The economic sector has emerged as the primary driver of national development, with strong interdependence among the industrial, agricultural, and economic sectors (Prasetyo, 2019; Dev, 2024).

The agricultural sector’s value-added model sheds light on various factors, such as education and skills, economic growth, government expenditure, nonfarming business income, the rural population, and technology. These factors converge to establish agriculture’s paramount importance as a primary means of livelihood for a substantial segment of the population. Furthermore, agriculture’s substantial contribution to gross domestic product, its role in ensuring food diversity, its support for both upstream and downstream industries, its positive effect on farmers’ income, its facilitation of entrepreneurial opportunities, and its significant contribution to foreign exchange earnings all underscore its multifaceted and indispensable contribution to fostering economic development, as highlighted by Costa et al. (2023) and Malik (2023).

The development of agriculture has a multifaceted objective, such as fostering resilient, advanced, and efficient agricultural practices. This leads to an increase in production yield; improving quality; elevating the income and living standards of farmers, livestock breeders, and fishermen; generating employment opportunities; nurturing entrepreneurial prospects; supporting industrial growth; and bolstering export capabilities (Li et al., 2023). While the initial focus of agricultural development primarily revolved around attaining self-sufficiency in rice production (Bishwajit et al., 2013; Pradhan et al., 2023), the time has come to explore and diversify into other agricultural commodities. To maximize farmers’ net income, the implementation of an optimal cropping pattern necessitates dynamic adjustments based on a comprehensive understanding of environmental conditions, market demand, and price fluctuations. The selection of suitable crop types for each year assumes critical significance, considering the inherent dependence of crops on their specific environmental requirements.

The agricultural landscape in India has undergone a remarkable transformation (Mishra et al., 2024), marked by a noteworthy surge in food grain production from a modest 51 million tonnes in 1950-51 to an impressive 316.06 million tonnes in 2020-21. However, this growth trajectory has been predominantly skewed toward cereal crops, while the production of pulses and oilseeds has failed to gain significant traction. Consequently, the nation is experiencing an enduring scarcity of edible oils and pulses, which presents a formidable challenge to address (Chand & Pal, 2003). In response to this scarcity, a discernible
shift in consumer preferences has emerged as individuals increasingly gravitate toward novel and high-value noncereal nutrient-rich diets. This shift manifests in a heightened emphasis on incorporating a diverse range of fruits and vegetables into their dietary choices (Joshi et al., 2004). The dynamic relationship between evolving consumer preferences and farmer reactions in adjusting their crop portfolios is an intriguing topic in the sphere of Indian agriculture. Diversification in this scenario appears in various forms, encompassing transitions between different crops, adjustments within specific crops, shifts across agricultural activities, and the incorporation of supplementary ventures to boost income generation through resource diversification and an expanded range of commodities. Moreover, diversification serves as a prudent means to mitigate unemployment and income volatility, ensuring a minimum standard of living that covers essential family expenses and loan repayments. In the specific case of Odisha, recent research has emphasized the crucial role of infrastructure in catalyzing crop diversification. Improved infrastructure has been observed to motivate farmers to adopt yield-enhancing practices and explore alternative crop choices. Interestingly, tribal-dominated areas with limited technological development display a greater inclination toward diversification. In their research, Nayak & Kumar (2019) demonstrated that tribal-dominated regions with lower technological development tend to exhibit a greater propensity for diversification. These studies shed light on the contrasting dynamics of agricultural practices across different regions of Odisha, influenced by factors such as infrastructure, agricultural backwardness, and technological development.

This paper addresses the question of how climate change affects agriculture, particularly cropping patterns, in the mining context of Odisha, India. The changes in crop patterns were analyzed, and the influencing factors leading to these changes in the Hemgiri Block of Sundargarh in Odisha were identified. Despite consistent efforts from agricultural policies, institutions, and development schemes, the agricultural livelihoods, such as paddy, vegetable, horticulture, and livestock livelihoods, of small and marginal farmers in the mining areas of the Hemgiri Block of Odisha continue to be unsustainable.

2. Methodology

The Hemgiri block of Odisha in India is located 52 kilometers away from the district headquarters in Sundargarh (Figure 1). The block consists of 143 villages and 84559 people (Census, 2011). This block has been experiencing increasing mining activities around coal. It is estimated that the Sundargarh region has reserves of more than 4 billion metric tons of iron ore, 2 billion metric tons of coal, and large deposits of manganese and limestone. The Sundargarh region contributes approximately 25-30% of the total iron ore production in Odisha, which represents a large portion of the total iron ore production in India; likewise, the region contributes approximately 15-20% of Odisha’s coal production annually (Directorate of Geology, n.d.). Mining activities in the Sundargarh region have led to the removal of thousands of hectares of forestland. It is estimated that more than 20,000 hectares of forestland have been cleared for mining purposes in the region, in addition to water pollution resulting from mining activities on many major rivers and water bodies in the region (Meher, 2009). It is estimated that approximately 50-60% of the water bodies in the region are contaminated with pollutants related to mining (B. P. Sahoo et al., 2021). Mining operations in the Sundargarh region also led to the displacement of approximately 50,000 to 60,000 people over the past decade, many of whom were farmers or agricultural workers (Gudavarthy & Sengupta, 2015). This displacement greatly affected local communities, leading to the loss of their livelihoods and cultural disruption. The Sundargarh region is considered highly vulnerable to the effects of climate change, which are exacerbated by mining activities. The inhabitants of this block largely depend upon agriculture. The main crops are paddies, pulses, and vegetables. The agriculture is mostly rain-fed. Hemgiri has 18951 ha. forestland, 2600 ha nonagri, use land, 1752 ha. barren land, 2244 ha. permanent pasture and grazing land and 26 ha. land under misc. tree, crop, groves, etc. It has 579692 indigenous and 20839 crossbred cows, 32933 buffalos, 563586 goats, 31744 sheep, 48349 pigs and 106437 poultry. The total milk production is 59.53 MT, the freshwater fish production is 1227 MT and the total egg production is 528.58 lakhs.

This study relied on collecting primary and secondary data, so to analyze the changes in cropping patterns and climate changes occurring in the Sundargarh district, it was necessary to gather secondary data from the official website of the Department of Agriculture in Odisha. These data included the cultivated areas of crops and minimum and maximum temperatures (see Table 1). Several mathematical formulas were applied to calculate climate changes and changes in the percentage of cultivated crops (formulas I and II).

The changes in cropping patterns were calculated based on a set of percentages as follows:

\[
\text{% of Net Sown Area (NSA)} = \frac{\text{Net sown area}}{\text{Total geographical area}} \times 100 \quad (I)
\]

\[
\text{% of area under crop} = \frac{\text{Area under the crop}}{\text{Gross cropped area}} \times 100 \quad (II)
\]

The changes in temperature within the same period were calculated using:

AVE: Average
SD: standard deviation
SIQOE: returns the slope of the linear regression line through the given data points.
RSQ: returns the square of the Pearson product-moment correlation coefficient through given data points.
The primary data were collected through the use of focus group discussions (FGDs) with a group of farmers in the study area, consisting of twenty groups in the Hemgiri Block. The discussions covered three topics: (1) market dynamics, (2) mining activities and their impact on agriculture, and (3) current cultivation and its needs, as well as climate change and its impact on agriculture. The groups were homogeneous and included marginal and small farmers, with a total of 20 groups. Farmer engagement was obtained through key informants, and each group was provided with the basic principles of participation. Each group session lasted approximately 40 minutes to one hour, and the discussions were recorded by an assistant who aided the researcher during the focus group sessions.

![Figure 1 Study area.](image)

**Table 1** Research data and time frame.

<table>
<thead>
<tr>
<th>Data used</th>
<th>Source</th>
<th>Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crops</td>
<td>Odisha Agricultural Statistics</td>
<td>From 2004-05 to 2018-19</td>
</tr>
<tr>
<td>Minimum and maximum</td>
<td>Odisha Agricultural Statistics</td>
<td>From 2005-06 to 2018-19</td>
</tr>
<tr>
<td>temperature</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. **Results**

Based on the analysis of the gross cropped area from 2004-05 to 2018-19, the results indicate a slowdown in the growth of gross cropped area for most crops. The linear regression equation for the change in gross cropping area is \( y = 0.0654x + 374.09 \), with a Pearson correlation coefficient value of 0.001. This value reflects the volatility and stagnation observed during these years, with a noticeable decline in the last three years (Figure 2).

Figure 3 illustrates the change in net sown area for the Sundargarh district as a whole, represented as a percentage of the total geographical area. The net sown area decreased from 32% to 28% of the total geographical area from 2004–05 to 2018–19.

![Figure 2 Gross cropped area in the Sundargarh District, 2004-05 to 2018-19.](image)
3. The main factors contributing to changes in cropping patterns

3.1. Mining activities in the Sundargarh District

Odisha is one of the richest states in India in terms of mineral resources (Ray & Saini, 2011). Mining activities in the state, including mining projects in Sundargarh, have resulted in significant displacement, particularly among farmers who are predominantly from tribal communities. Approximately 56,382.89 hectares of land were converted into developmental projects in Odisha by March 2020. Mining activities alone account for the largest area, constituting 50.39% of the total forestland converted for nonforest use, covering an area of 28,409.53 hectares.

Source: Calculated from the Odisha Agricultural Statistics.
This displacement movement was one of the livelihood strategies adopted as a result of changes in the external environment, which have impacted assets and agricultural activities (Oraon, 2012). According to discussions among farmers in focus groups, staying on the land means employing methods to mitigate the impact of mining on agricultural lands, including the increased use of chemical fertilizers, which would result in increased environmental pollution. Additionally, it contributes to the use of chemical pesticides. According to the farmers, the use of chemical fertilizers does not solve this problem due to inefficient farming practices and the significant financial, environmental, and social losses incurred by farmers, especially in mining areas. For example, farmers in intensive discussion groups in the Hemagiri Block explained the following:

- The daily influx of 1200 to 1600 trucks through villages leads to severe air pollution, as the emission of black dust particles causes paddy crops to suffer from reduced photosynthesis.
- Rice crops are experiencing a detrimental blackening color due to the settling of black dust particles, resulting in a significant decline in consumer demand for this discolored rice.
- The presence of open-cast coal mines, including MCL, NTPC, and OPCL, in Hemagiri causes detrimental pollution to nearby water bodies, thereby adversely impacting agricultural practices in the area.
- The rapid drainage of rainwater within 2-3 days, as opposed to that in the previous 10-15 days, quickly dries out the fields.
- The water table in the region is experiencing a decline, as evidenced by observations from wells and the need to dig deeper bore wells to access groundwater.
- Paddy yield has significantly decreased to 10-12 quintals per acre due to the adverse effects of mining operations, which is a stark reduction from the previous yield of 20-25 quintals per acre.
- The settling of mining dust on crops, particularly paddies, is affecting their marketability, making it increasingly challenging for them to be sold on the market.
- The pollution caused by mining dust also impacts the availability of fodder for animals, as the grass and other vegetation necessary for livestock are being affected.
- The degradation of the taste and quality of edible greens such as drumstick leaves and vegetables, including bitter gourd and papaya, results in a diminished preference for these food items within the community.
- Water bodies in the area are heavily polluted, characterized by the presence of black layers, leading to an increase in skin diseases among the local population.
- The pollution caused by mining activities disrupts the availability and livelihood opportunities associated with nontimber forest products (NTFPs), such as mahua flowers, sal leaves, and char.
- During rainfall, the water from the mines flows into Chaturdharanala, which eventually merges with Basundharanala and continues downstream toward Laikera.
- In addition to environmental concerns, heavy truck traffic related to coal transportation is increasing the risk of accidents and contributing to the emergence of social issues within the community.

### 3.1.2. Climate change

Changes in the maximum and minimum temperatures were studied for each month from 2004 to 2018. The average temperatures, standard deviations, trends, and Pearson correlation coefficients were calculated. The results revealed a negative deviation trend in maximum temperatures in the sixth month during the study period. A low Pearson correlation coefficient indicates significant fluctuations in temperature during the most critical months for farmers, particularly at the beginning of the Kharif season (from June to September), which coincides with the rainy season in the district.

### 3.1.3. Government Programs and Interventions for Changing Agricultural Patterns

Interventions were implemented in the Sundargarh region through the Valley Project, covering approximately 500 acres of land. The project aimed to enhance food security for households affected by mining activities. It commenced in 2020 and was designed to span seven years. The project focused on several crops, including lychee, cashew, and mango (Acharya & Patnaik, 2018). Figure 5 illustrates the change in mango cultivation area in the study area.
Table 4 Temperature statistics in the Sundargarh District (from 2005-06 to 2018-19).

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature AVE</th>
<th>STD</th>
<th>SLOPE</th>
<th>RSQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>Max 27.971</td>
<td>1.909</td>
<td>-0.046</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>Min 10.614</td>
<td>1.437</td>
<td>0.062</td>
<td>0.033</td>
</tr>
<tr>
<td>Feb</td>
<td>Max 31.650</td>
<td>1.498</td>
<td>0.012</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Min 14.643</td>
<td>4.648</td>
<td>0.258</td>
<td>0.054</td>
</tr>
<tr>
<td>Mar</td>
<td>Max 34.657</td>
<td>6.098</td>
<td>-0.347</td>
<td>0.057</td>
</tr>
<tr>
<td></td>
<td>Min 18.529</td>
<td>4.586</td>
<td>0.147</td>
<td>0.018</td>
</tr>
<tr>
<td>Apr</td>
<td>Max 38.271</td>
<td>6.736</td>
<td>-0.306</td>
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<tr>
<td></td>
<td>Min 21.986</td>
<td>1.364</td>
<td>-0.014</td>
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<tr>
<td>May</td>
<td>Max 41.057</td>
<td>1.339</td>
<td>-0.069</td>
<td>0.046</td>
</tr>
<tr>
<td></td>
<td>Min 25.464</td>
<td>4.559</td>
<td>0.069</td>
<td>0.004</td>
</tr>
<tr>
<td>Jun</td>
<td>Max 36.536</td>
<td>4.366</td>
<td>-0.353</td>
<td>0.115</td>
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<td></td>
<td>Min 25.071</td>
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<td>0.005</td>
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<tr>
<td>Jul</td>
<td>Max 30.979</td>
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<td>-0.108</td>
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<tr>
<td></td>
<td>Min 22.729</td>
<td>1.238</td>
<td>-0.217</td>
<td>0.539</td>
</tr>
<tr>
<td>Aug</td>
<td>Max 30.350</td>
<td>2.237</td>
<td>0.113</td>
<td>0.045</td>
</tr>
<tr>
<td></td>
<td>Min 22.593</td>
<td>1.138</td>
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<td>0.278</td>
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<tr>
<td>Sep</td>
<td>Max 32.007</td>
<td>1.060</td>
<td>-0.121</td>
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</tr>
<tr>
<td></td>
<td>Min 22.607</td>
<td>0.867</td>
<td>-0.115</td>
<td>0.305</td>
</tr>
<tr>
<td>Oct</td>
<td>Max 31.564</td>
<td>1.892</td>
<td>-0.251</td>
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<tr>
<td></td>
<td>Min 19.357</td>
<td>0.892</td>
<td>0.055</td>
<td>0.065</td>
</tr>
<tr>
<td>Nov</td>
<td>Max 29.607</td>
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<td>-0.095</td>
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<tr>
<td></td>
<td>Min 14.293</td>
<td>1.584</td>
<td>-0.032</td>
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<tr>
<td>Dec</td>
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<td>0.065</td>
</tr>
<tr>
<td></td>
<td>Min 10.179</td>
<td>1.103</td>
<td>-0.093</td>
<td>0.126</td>
</tr>
</tbody>
</table>

Source: Odisha Agricultural Statistics.

Figure 4 Area of mango during the period 2000-01 to 2018-19 in the Sundargarh District. Agricultural statistics (000 ha).

3.1.4. Market Dynamics and Changes

According to the 2011 statistics, the Sundargarh region is home to 2,093,437 individuals. The arable land available for agriculture is 291,000 hectares, which is significantly less than the food requirements of the population. In 2017, the per capita vegetable requirement was approximately 80.8 kilograms per month. Hence, there is considerable demand for vegetables. The cultivated area is generally dedicated to growing grains and vegetables (Kerketta & Mahalik, 2022). During times of crisis, people often struggle to find an adequate quantity of food to consume. The labor-intensive nature of fieldwork, coupled with low prices for staple crops such as rice, has posed challenges (Mishra, 2007). Consequently, in recent years, according to discussions in focus groups, the population has shifted away from rice cultivation and toward more profitable crops such as pulses and fruits, including mangoes and cashews.

3.1.5. Additional factors

A. Land ownership patterns and availability of technological resources:
The prevailing land ownership system in Sundargarh poses potential challenges to effective agricultural cultivation. The majority of farmers in the area rely on wage labor, leading to reduced agricultural yields. Furthermore, limited access to expensive fertilizers and advanced technological equipment necessary for optimizing productivity further compounds this issue. Consequently, marginal and small-scale farmers bear a disproportionate burden of high production costs.

B. Diminished crop productivity

The adverse effects of soil erosion, fragility, and a progressive decline in productivity on the agricultural landscape of Sundargarh grapple with a significant reduction in agricultural output and consequential alterations in crop patterns. Within this context, numerous agricultural and horticultural crops cultivated in the region exhibit alarmingly low yields that fail to meet the demands of the market or adequately sustain the burgeoning population’s needs.

C. Shifting occupational dynamics:

A discernible catalyst behind the diminishing agricultural output in the Sundargarh district is the prevalent phenomenon of young individuals opting for occupational change, with an estimated 60% of them transitioning from agriculture to the service sector. This substantial shift is motivated by a prevailing sentiment that agriculture is inherently ineffective, resulting in outputs deemed inconsequential and prompting widespread disillusionment with the sector.

D. Educational level:

In the Sundargarh district, there has been a discernible surge in education, as evidenced by an upward trajectory in literacy rates according to the 2011 census. This development has been accompanied by the expansion and proliferation of educational institutions within the region. Consequently, the agricultural sector has witnessed a decline in its capacity to generate employment opportunities relative to the flourishing education sector. Notably, educated rural youth now exhibit a distinct inclination toward pursuing careers in the education sector rather than participating in traditional agricultural practices.

5. Conclusion

In conclusion, the findings of this study indicate gradual but limited progress in crop diversification within the Sundargarh district. While paddy cultivation continues to dominate agricultural landscapes, there has been a discernible shift toward nonpaddy crops such as pulses, oilseeds, and fruits. However, it is important to note that the overall gross cropped area has been decreasing due to the diversion of agricultural land for infrastructure development projects. Furthermore, the study highlights a notable preference among the younger generation for employment in the service sector, driven by the perception of higher remuneration compared to the agricultural sector. Given the significant contribution of the service sector to the region’s economy, it is imperative to enhance the productivity and profitability of agricultural activities, particularly to attract and retain the interest of young people. Policy interventions aimed at incentivizing and promoting sustainable agricultural practices can play a pivotal role in addressing these challenges. These research findings can serve as a valuable resource for the government of Odisha in formulating appropriate policies and strategies to foster agricultural development in the district.

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Ethical considerations

Not applicable.

Conflict of Interest

The authors declare no conflicts of interest.

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References


