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## Opportunities and Challenges for Adoption of Agricultural Modernization in Bundelkhand Region of India

Dr. P. K. Ahirwar<sup>1</sup>

<sup>1</sup>Department of Geography, Raja Harpalsingh Government College Harpalpur, Chhatarpur (M.P)

\* Corresponding author. E-mail- pkahirwar357@gmail.com

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### ABSTRACT

This research paper analyzes the opportunities and challenges for the adoption of agricultural modernization in the Bundelkhand region of India, based on its interconnected ecological factors. Modern agriculture holds significant potential for future employment opportunities and prospects in this region, which is particularly well-suited for such advancements. However, most farmers still utilize modern agricultural techniques to a very limited extent. This is because farmers face several challenges in adopting modern agricultural practices, such as small landholdings, uneven terrain, infertile soil, lack of irrigation facilities, and limited access to innovation and adoption of new technologies, all of which directly impact agricultural activities. The socio-economic constraints of the farmers is a particularly significant challenge. Therefore, it is crucial to develop a new direction for emerging agricultural development in this region and address the challenges associated with the adoption of modern agricultural technologies. This will enable integrated and sustainable modern agricultural development in the region.

### Introduction

This research study analyzes the process of adoption by farmers, the opportunities presented by new technological methods, and the challenging factors affecting agriculture within the context of agricultural modernization in the Bundelkhand region. Agricultural modernization encourages farmers to adopt innovative farming practices, provides new opportunities, enhances their skills and capabilities, facilitates the process of agricultural innovation and adoption, increases farmers' income, and improves efficiency and productivity. However, most farmers in this region utilize the various technological methods associated with modern agriculture only to a very limited extent. This is because factors such as fragmented landholdings, lack of irrigation facilities, lack of awareness, lack of information, and problems with the use of agricultural machinery directly affect the opportunities for adopting modern farming practices. Consequently, farmers in this region face several challenges in the pursuit of modern agriculture. The most significant challenge is the socio-economic factors that influence them both directly and indirectly. This results in a low level of adoption and agricultural modernization in the region (Sharma, 1998, 165-177).

Therefore, for the development of modern agriculture in this region, it is crucial to raise awareness among farmers about government agricultural schemes and facilities and to address the challenges posed by the current circumstances. This will enable integrated and sustainable modern agricultural development in the region.

#### Study Area

Bundelkhand region is a geographical and cultural region of central India, which is also a semi-arid plateau. This region is spread from the Ganges Yamuna plain in the north to the Vindhyachal mountain ranges in the south. It is a moderately sloping highland region. The height of the Bundelkhand region is 600 meters above sea level. This region is located between UP and MP. The average rainfall in this region is around 60-100 cm. Therefore, the variability

of rainfall in this region, lack of agricultural facilities and socio-economic status of farmers etc. are the most problematic challenges for the development of modern agriculture, which directly and indirectly affect agricultural activities (Dayal, 1989, 475-489). The study area of Bundelkhand is shown in Figure 1.



This region is 23°10' to 26°27' north latitude and 78°4' to 81°34' east longitude. A total of 14 districts are included in the Bundelkhand region. These include 7 districts of UP and 7 districts of MP. These include Banda, Chitrakoot, Hamirpur, Mahoba, Jalaun, Jhansi and Lalitpur of UP and Sagar, Damoh, Chhatarpur, Tikamgarh, Niwari, Panna and Datia districts of MP. Apart from this, 9 districts are spread outside this region, which are partially connected to tourism areas. That is, the opportunities and challenges related to agricultural modernization have been studied in a total of 14 districts of this region. Similarly, the opportunities and challenges of modern agriculture have been analyzed on the basis of a survey of selected farmers in this region.

The total population of Bundelkhand is about 18,311,896 people in 2011. They constitute about 1.51 percent of the total population of the Indian. Out of which 14,198,668 people live in rural areas. Out of the total population 9,712,067 are male and 8,599,829 are females. The sex ratio of this area is 877 and literacy

is 48.41 percent. Similarly, less than 60 percent of the literate population in this region lives in rural areas. Thus, relative to the state of UP, the population resides in almost equal percentage in rural and urban areas.

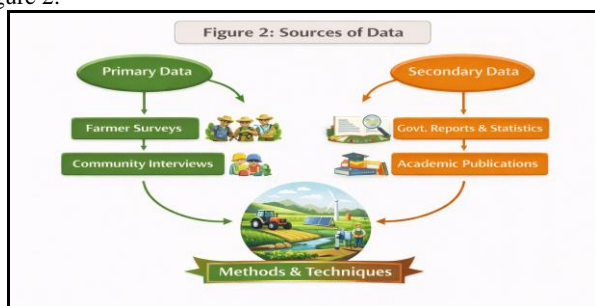
**Objectives:** The objective of this study is to examine the differences found among various land-holding categories and communities with regard to the adoption of agricultural modernization, which are as follows:

1. To analyze the opportunities of agricultural modernization in Bundelkhand for productivity, employment, and sustainable development.

2. To examine the major challenges affecting adoption, including socio-economic constraints, small landholdings, and irrigation issues.

### Methods and Techniques

The total number of villages in Bundelkhand region is 105602. Therefore, it is very difficult to survey each and every farmer household. Similarly, out of total 14 districts of this region, a total of 1500 selected farmer family surveys. In which 7 districts of MP and 7 districts of UP have been included. Therefore, agricultural information has been collected on the basis of primary data and secondary. The sources of data collection are shown in Figure 2.



The data have been analyzed using the Comparative Z-Score Methods (CZS), primarily on the basis of size of landholdings and community. Information related to the adoption of modern agricultural practices was collected through a structured interview method using a questionnaire consisting of 116 questions, focusing on factors influencing the adoption of modern agricultural techniques. The questionnaire mainly emphasized the collection of data on 18 variables associated with agricultural modernization, which are considered key agricultural technologies. Furthermore, the analysis of the opportunities and challenges of agricultural modernization is based on a sample survey of selected farmers in the region, taking into account their community and landholding characteristics. The farmers were interviewed directly, and the study is based on household-level data, capturing their information and perspectives for the present research.

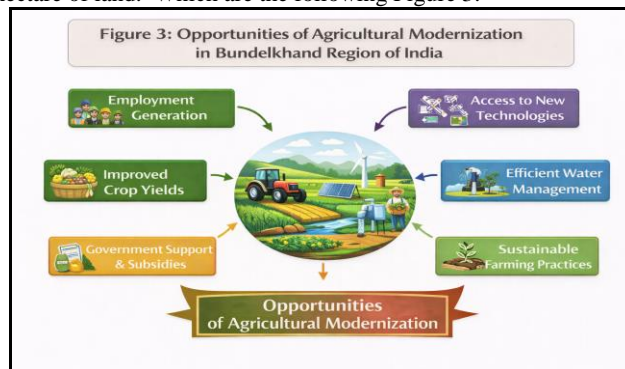
### Review of Literature

Literature review has been done to understand the real nature of modern agriculture and to finalize the research study. Because this analysis exposes the agricultural tension prevailing among the farmers. In which it shows their efficiency and capacity in the use of inputs under agriculture. Along with this, it provides opportunities for innovation and technical methods used in the process of modern agriculture. Therefore, it renders the adoption process of farmers extremely challenging towards agriculture. On the other hand, this analysis is sensitive to the new trends of farmers changing towards modern agriculture.

### Opportunities :

At present, it is very important to understand agricultural activities to promote modern farming. Because even today some farmers are not able to use the new methods of agriculture. Due to which the production capacity of the crops is adversely affected. But due to the modern development of agriculture, there has been a change in the technical methods related to agriculture. Therefore, by using new inputs of agriculture, the farmer can produce crops according to his land capacity. That is, there are potential

opportunities for farmers to increase the production capacity per hectare of land. Which are the following Figure 3.



The flow chart illustrates the major opportunities associated with agricultural modernization in the Bundelkhand region of India. The central image represents modern agriculture, symbolizing the integration of mechanization, renewable energy, improved irrigation systems, and technological interventions in farming practices. The surrounding components highlight the key benefits and developmental prospects emerging from this modernization process. **Employment Generation:** Employment generation is one of the key opportunities of agricultural modernization in India. Nearly 45 percent of the workforce depends on agriculture for livelihood in this region. Besides, more than two-third (70 percent) of the rural population relies on agriculture and related activities. The adoption of modern practices such as mechanization, agro-processing, and improved supply chains creates new jobs in machinery operation, maintenance, and food processing sectors. Therefore, agricultural modernization can significantly increase rural employment and reduce migration in the Bundelkhand region.

**Improved Crop Yields:** Improved crop yields are a major outcome of agricultural modernization in India. The average yield of wheat is about more than three tons per hectare, while rice yields are around four tons per hectare, mainly due to the use of modern farming techniques. The adoption of high-yielding variety (HYV) seeds, mechanization, and improved irrigation can increase crop productivity more than two-fifths (40 percent) compared to traditional farming. In regions like Bundelkhand, where yields are often lower than the national average, modernization can significantly improve farm output. As a result, higher productivity leads to increased farm income and better food security for farmers.

**Access to New Technologies:** Access to new technologies is another crucial opportunity in agricultural modernization in India, farm mechanization has increased significantly, with tractor availability rising to about 30 tractors per 1,000 hectares of agricultural land. Digital agriculture tools and mobile-based advisory services now reach over 50 million farmers across the country. The adoption of modern irrigation systems such as drip and sprinkler irrigation can improve water-use efficiency by more than 45 percent. In addition, renewable energy programs like PM-KUSUM promote solar-powered irrigation pumps, helping farmers reduce energy costs and production risks.

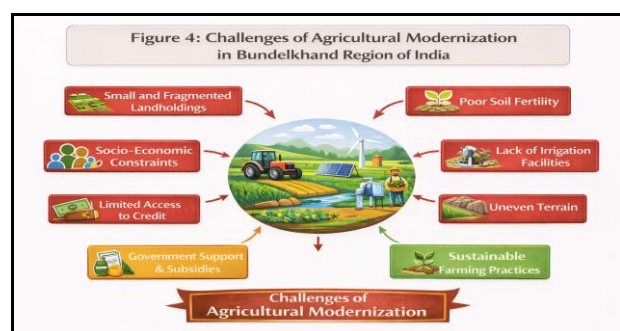
**Efficient Water Management:** Efficient water management is essential in drought-prone regions like Bundelkhand. The region receives an average annual rainfall of about 700–900 mm, but irregular distribution often leads to water scarcity for agriculture in India. Besides, more than half (50 percent) of the net sown area is irrigated, while the rest depends on rainfall. Modern irrigation methods such as drip and sprinkler systems can reduce water use while maintaining crop productivity. Therefore, efficient water management can significantly improve agricultural sustainability and reduce drought risks in Bundelkhand.

**Government Support and Subsidies:** Government support and subsidies play a crucial role in promoting agricultural modernization in India. Government schemes such as Pradhan Mantri Krishi Sinchai Yojana and Pradhan Mantri Fasal Bima Yojana provide financial assistance, irrigation support, and crop insurance to millions of farmers. The Indian government allocates over one lakh

crore rupees annually for agricultural subsidies, including fertilizer, irrigation, and credit support. These initiatives help farmers access modern inputs, technology, and infrastructure. As a result, government support also encourages sustainable farming practices such as soil conservation, efficient water use, and climate-resilient agriculture.

**Sustainable Farming Practices:** Sustainable farming practices are an important outcome of agricultural modernization in India. More than one-thirds (33 percent) of agricultural land is affected by soil degradation, making sustainable practices essential for long-term productivity. Techniques such as crop diversification, organic farming, and integrated pest management help improve soil fertility and reduce environmental damage. According to agricultural studies, sustainable practices can improve soil health and increase productivity about 20 percent over time. Therefore, modernization supports environmental sustainability and promotes long-term rural development in regions like Bundelkhand.

**Challenges :** Challenges of human elements are the most active elements and determined by the activities on its capability and capabilities of the farmers such as socio-economic challenges directly affect agricultural modernization. Besides challenges farmers face due to remoteness in rural areas such as no accessibility of transport and communication reach in villages farmers. The challenges of agricultural modernization are shown in Figure 4.



The flow chart clearly illustrates the major challenges hindering the process of agricultural modernization in the Bundelkhand region of India. The diagram places modern agriculture at the center, indicating that despite the availability of improved technologies, several interconnected constraints limit their effective adoption by farmers.

**Small and Fragmented Land Holdings:** Small and fragmented landholdings are a major challenge for agricultural modernization. The regional average landholding size has declined to about 1.08 hectares, according to agricultural census data. Nearly 86 percent of farmers are small and marginal farmers, owning less than 2 hectares of land. Such fragmented holdings make it difficult to adopt mechanization and modern farming technologies efficiently. As a result, limited land size reduces productivity, investment capacity, and the economic viability of advanced agricultural practices.

**Poor Soil Fertility:** Soil fertility is a major constraint affecting agricultural productivity in India. Nearly 33 percent of agricultural land is affected by soil degradation and nutrient deficiency. Low organic carbon levels, often below 0.5 percent in many soils, reduce soil fertility and crop yields. In regions like Bundelkhand, soil erosion and inadequate nutrient management further worsen soil quality. As a result, poor soil fertility significantly limits crop productivity and the adoption of modern agricultural practices.

**Socio-economic Constraints:** Socio-economic constraints significantly affect the adoption of modern agricultural practices in India. Besides 86 percent of farmers are small and marginal, often having limited income and resources. According to surveys, about 35 percent of rural farmers have limited access to formal credit institutions. Low education levels and lack of awareness about modern technologies further restrict adoption. Consequently, these socio-economic barriers reduce farmers' capacity to invest in improved inputs, machinery, and advanced farming methods.

**Lack of Irrigation Facilities:** Irrigation facilities are a major constraint in drought-prone regions like Bundelkhand in India. About 55 percent of the net sown area is irrigated, while the remaining agricultural land depends on rainfall in the Bundelkhand. Thus a large proportion of farm land is rain-fed, making farmers highly vulnerable to irregular rainfall. The region receives about 700–900 mm of annual rainfall, but its uneven distribution often causes water shortages. Consequently, limited irrigation facilities increase production risks and restrict the adoption of modern agricultural technologies.

**Limited Access to Credit:** Limited access to credit is a major challenge for small and marginal farmers in Bundelkhand. The regional average about 86 percent of farmers belong to the small and marginal category, often lacking sufficient financial resources in India. Studies indicate that nearly 35 percent of farmers have limited access to formal banking and institutional credit. As a result, many farmers depend on informal lenders who charge very high interest rates. This lack of affordable credit restricts farmers from investing in modern inputs, machinery, and improved agricultural technologies.

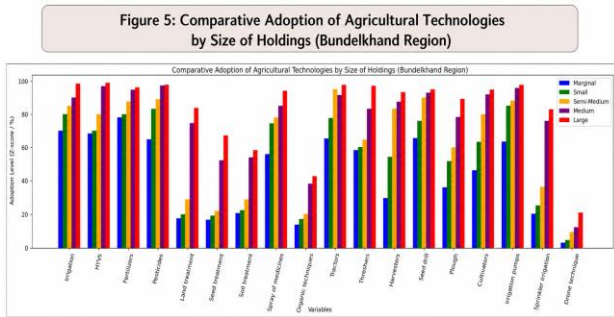
**Uneven Terrain:** Terrain is another challenge that affects agricultural modernization in this Bundelkhand region. Therefore a significant portion of agricultural land consists of rocky and undulating terrain, which makes farming operations difficult. Studies indicate that nearly more than one-third percent of the land in Bundelkhand is affected by uneven topography and soil erosion. Such land conditions limit the effective use of tractors and other modern farm machinery. Consequently, uneven terrain reduces farming efficiency and restricts the adoption of large-scale modern agricultural practices.

#### **View About the Farmers related to Adoption and Agricultural Modernization (Based on Sample Survey)**

The view about farmers related to the adoption of agricultural modernization is analyzed on the basis of a sample survey. It highlights farmers' perceptions, awareness, and willingness to adopt modern agricultural techniques. The study considers socio-economic factors such as landholding size and community background influencing adoption. It also reflects the role of education, access to resources, and institutional support in shaping farmers' decisions (Ahirwar, 2025, 79-86). The study examines farmers' perspectives on the adoption of agricultural modernization based on a sample survey conducted in the selected region. It focuses on how socio-economic factors such as education, community, and size of landholdings influence the adoption of modern agricultural practices. The data were collected through direct interviews at the household level to understand farmers' awareness, attitudes, and decision-making behavior. The analysis highlights variations in adoption levels among different categories of farmers and identifies key opportunities and constraints. Overall, the findings provide insights into the role of farmers' characteristics in shaping the process of agricultural modernization (Rogers 2003, 576).

**Size of Holdings:** Marginal farmers have the lowest adoption rates of modernization techniques and equipment. For example, only 70.2 percent use irrigation, and 16.9 percent use seed treatment. This indicates that marginal farmers face significant challenges in adopting modern agricultural practices. Small farmers show slightly higher adoption rates than marginal farmers. For instance, 80.2 percent use irrigation, and 19.2 percent use seed treatment. However, their adoption of advanced techniques like organic techniques (17.1 percent) and drone technique (4.7 percent) remains low. Semi-medium farmers exhibit increased adoption of modernization techniques. For example, 85.0% use irrigation, and 21.5 percent use seed treatment. They also show higher usage of equipment like tractors (95.8 percent) and harvesters (83.5 percent). Medium farmers have high adoption rates of modern techniques, with 90.5 percent using irrigation and 52.2 percent using seed treatment. They also utilize equipment like tractors (92.0 percent) and cultivators (92.5 percent) extensively. Large farmers have the highest adoption rates of all modernization techniques and equipment. For example, 99.1 percent use irrigation, and 66.6

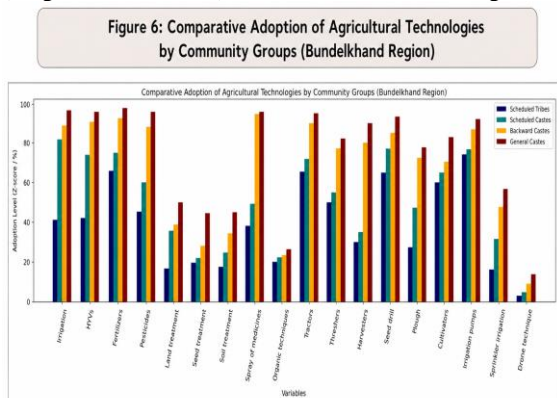
percent use seed treatment. They also show maximum usage of advanced equipment like harvesters (93.7 percent) and sprinkler irrigation 83.1 percent among all sizes of the farmers (Palsaniya, 2025, 323-330). This variation shows in Figure 5.



Source: Based on 1500 Households Sample Survey.

The adoption of agricultural modernization techniques and equipment increases with the size of land holdings. Larger farms have better access to resources and technical knowledge, enabling higher adoption rates. They would like to focus on a specific farm size for further analysis or need insights on improving adoption among small and marginal farmers (Ojha, 2025, 137-141).

**Communities:** The comparative analysis of agricultural technology adoption in the Bundelkhand region shows clear disparities among communities based on percentage levels. General castes exhibit the highest adoption, exceeding 95 percent in most modern technologies, indicating strong access to resources and awareness. Backward castes follow with relatively highest adoption ranging more than seven-tenths (70 percent) especially in fertilizers, pesticides, and basic machinery. Scheduled castes show moderate adoption levels of around more than half (50 percent), reflecting partial inclusion in agricultural modernization. In contrast, scheduled tribes record the lowest adoption, generally more than one-thirds (30 percent), highlighting significant technological and economic constraints. The gap is most evident in capital-intensive technologies like tractors and harvesters, where adoption exceeds eight-tenths (85 percent), among general castes but remains less than two-thirds (40 percent) for scheduled tribes. Basic inputs such as fertilizers and pesticides are widely used but still show variation across communities. Irrigation facilities also reflect inequality, with high adoption among advanced groups and limited access among marginalized communities. Innovative technologies like organic farming and drones remain low across all groups, especially among scheduled tribes. The overall pattern shows a gradual increase in adoption from scheduled tribes to general castes. This comparative trend clearly indicates that socio-economic status and community identity strongly influence agricultural modernization in the region (Singh, 2024, 380-385). This variation shows in Figure 6.



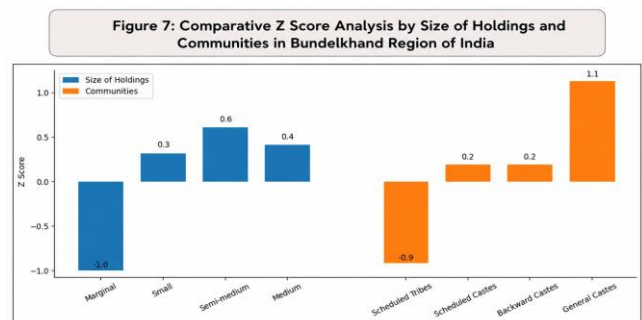
Source : Based on 1500 Households Sample Survey.

The data confirm that community identity plays a crucial role in influencing technology adoption patterns in the region. Lower adoption among marginalized groups is largely due to limited capital, lack of awareness, and inadequate institutional support. Therefore, targeted interventions are essential to bridge this gap and

ensure inclusive agricultural modernization. Community-specific extension programs for scheduled tribes and scheduled castes should be designed to improve access to training and modern technologies. Additionally, subsidies and financial assistance for machinery and innovative practices like organic farming and drone use should be promoted. Continuous monitoring of adoption levels is necessary to evaluate the impact of these interventions on productivity and social equity (Joshi, 2026, 381-388).

**Comparative Z Score Analysis by Size of Holdings and Communities:**

Comparative Z-score analysis is based on standardizing percentage values obtained from the sample survey. First, the percentage adoption of each technology is calculated for all categories (size of holdings or communities) based on the sample households. Second, the mean (average) of these percentage values is computed. Third, the standard deviation (SD) is calculated to measure variation among the percentages. Fourth, the Z-score is obtained using the formula:  $Z = (X - \text{Mean}) / \text{SD}$ , where X is the percentage value of a category. Fifth, positive Z-scores indicate above-average adoption, while negative values indicate below-average adoption. Finally, this method allows comparison across different groups in a standardized manner based on the sample data. This variation scores shown in Figure 7.



Source: Based on 1500 Households Sample Survey.

The comparative Z-score graph highlights clear disparities in agricultural modernization across farm sizes and social communities in the Bundelkhand region. The analysis shows that marginal farmers have the lowest Z-score (-1.0), indicating lowest adoption of modern agricultural technologies. Small farmers (0.3) and semi-medium farmers (0.6) show gradual improvement, reflecting increasing access to resources and inputs. Medium farmers (0.4) also maintain a positive adoption level, though slightly lower than semi-medium farmers. Among communities, scheduled tribes record the lowest Z-score (-0.9), signifying very limited technological adoption. Scheduled castes (0.2) and backward castes (0.2) demonstrate moderate adoption, indicating some level of inclusion in modernization processes. General castes exhibit the highest Z-score (1.1), reflecting strong access to advanced technologies and resources. The wide gap between scheduled tribes and general castes highlights significant socio-economic inequalities in the region. Similarly, the variation across landholding sizes confirms that farm size plays a crucial role in determining adoption levels. Overall, the graph establishes that both economic capacity and social structure are key determinants of agricultural modernization (Sharma, 2012, 145-158). The findings emphasize the need for targeted policy interventions to bridge these disparities and promote inclusive agricultural development.

**Conclusions:**

Agricultural modernization in Bundelkhand offers significant potential to improve rural livelihoods and strengthen the regional economy. The use of modern technology, improved seeds, and farm mechanization can increase agricultural productivity. Efficient irrigation systems and water management practices can help reduce the impact of drought. Government schemes and financial support can encourage farmers to adopt innovative methods. Modernization also promotes crop diversification and agro-based industries. This can generate employment opportunities and reduce seasonal migration. Sustainable farming practices can improve soil health

and long-term productivity. However, the region faces serious challenges such as water scarcity and irregular rainfall. Small and fragmented landholdings limit large-scale technological adoption. Many farmers lack access to credit and modern equipment. Poor infrastructure, storage, and market facilities reduce profit margins. Low awareness and limited technical knowledge slow down progress. Climate change further increases agricultural risks and uncertainties. Social and economic inequalities also affect inclusive development. Therefore, balanced policies, proper training, and sustainable resource management are essential for successful agricultural modernization in Bundelkhand.

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