SHODH SAMAGAM

ISSN : 2581-6918 (Online), 2582-1792 (PRINT)

Crop Diversification : An Effective Strategy for Sustainable Agriculture in Chhattisgarh

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ORIGINAL ARTICLE

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Received on : 15/04/2025
Revised on : 16/06/2025
Accepted on : 25/06/2025
Overall Similarity : 09% on 17/06/2025

ABSTRACT

Agriculture is the backbone of Chhattisgarh's economy, where the majority of people are dependent, either directly or indirectly, on farming for a satisfactory livelihood. However, resource degradation, fluctuating rainfall patterns, and falling productivity underline the urgency of urgent imperatives that need to be undertaken toward sustainable agriculture. Crop diversification-that is, shifting from traditional monoculture systems to diverse cultivation-appears as a very feasible option toward enhancing sustainability, economic resilience, and environmental health. This paper has discussed in detail the role of crop diversification in the sustainable agricultural development of Chhattisgarh in view of the current agricultural trend in the region, benefits, and challenges in the adoption of crop diversification with some actionable strategies to realize its potential. The results of the study shows that the Crop Diversification Index reveals notable differences in agricultural diversification among the agro-climatic zones of Chhattisgarh. The Plains demonstrate considerable diversity, whereas the Northern Hills and Bastar Plateau fall short, predominantly depending on conventional farming methods. To tackle these regional imbalances, implementing focused interventions, improving infrastructure, and developing farmer-oriented policies can foster sustainable agricultural development and improve income stability for farmers in Chhattisgarh.

KEY WORDS

Agriculture, Crop Diversification, Economic Resilience, Environmental Health, Sustainable Agriculture.

INTRODUCTION

Chhattisgarh, often referred to as the "Rice Bowl of India," is predominantly under paddy monoculture, leading to soil degradation, scarcity of water, and economic vulnerability due to market fluctuations. Crop diversification would bring opportunities for such challenges with the introduction of diverse climatic, ecological, and economic requirements of crops. This crop diversification, in tune with sustainable agricultural development goals, would encourage biodiversity, improve soil health, and stabilize farmers' incomes.

Agricultural Landscape of Chhattisgarh

The major characteristic of the agriculture of Chhattisgarh is as follows:

1. **High Dependence on Paddy Cultivation:** Paddy is covering more than 80% of the area under cultivation, drawing strength from traditional preferences and government support for procurement.
2. **Climatic Vulnerability:** As more than 70% of the area falls under rainfed agriculture, the state is highly vulnerable to erratic monsoons.
3. **Marginal and Small Landholders:** Over 76% of farmers are smallholders that have limited access to technology, credit, and markets.

This overdependence on paddy has reaped consequences of overexploitation of the resource base, especially water, at the cost of more viable and diversified crop systems.

Crop diversification is an essential strategy for promoting sustainable agriculture, effectively balancing environmental, economic, and social objectives. This method entails growing a range of crops on the same land, which decreases reliance on a single crop or farming method. By doing so, it enhances the resilience of agricultural systems, helping to mitigate risks related to pests, diseases, climate changes, and market volatility, thus serving as a viable approach for ensuring long-term agricultural sustainability.

A significant advantage of crop diversification is its beneficial effect on soil health. Monocropping, or the continuous cultivation of one crop, can lead to nutrient depletion in the soil, resulting in diminished fertility over time. By incorporating a variety of crops, farmers can enhance nutrient cycling, as different plants have unique nutrient needs and contribute to soil enrichment in various ways. For example, legumes are known to fix nitrogen in the soil, which can be advantageous for subsequent crops. This natural process of replenishment reduces the necessity for chemical fertilizers, thereby lowering costs for farmers and decreasing environmental pollution. Thus, the broad objective of the study is to analyze the crop diversification pattern in Chhattisgarh across different agroclimatic zones.

Review of Literature

Paroda, R. (2022) highlights that in India, the development of cropping systems has resulted in the availability of more productive and lucrative options for farmers. Significant instances include the rice-wheat system prevalent in the northern regions, groundnut farming in Gujarat, sugarcane cultivation in the north, chickpea production in the southern states, arhar in the northwestern territories, soybean in Madhya Pradesh and adjacent areas, and winter maize in Bihar. Nevertheless, many of these systems necessitate diversification to improve sustainability and preserve natural resources. It is crucial to enact reforms in the existing cropping systems that are based on scientific principles and adapted to various agro-climatic conditions. This analysis delineates possible pathways for crop diversification that can enhance farmers' yields and income while fostering conservation agriculture through sustainable intensification. A comprehensive long-term strategy for crop diversification is imperative for the overall advancement of the nation. Upadhaya, et al (2022) emphasized that mono-cropping practices within the agricultural framework are associated with diminished farm profitability, the repercussions of climate change, and heightened food insecurity, all of which play a role in the unsustainable nature of agricultural production in the Eastern Gangetic Plains. A three-year investigation conducted from June 2019 to June 2022 at Dr. Rajendra Prasad Central Agricultural University in Pusa, Bihar, India, sought

to assess the most profitable and efficient rice-based cropping systems through crop diversification aimed at sustainable agriculture. The study employed ten unique cropping sequences organized in a randomized block design, replicated three times, with system productivity ranging from 8.70 to 24.95 t ha”1 across the various sequences. Significantly, the maize–cole crops–sesame cropping system exhibited an extraordinary increase in system productivity by 187% and profitability by 299.52% when compared to the conventional rice–wheat cropping system. Additionally, a diversified cropping system that included black gram, maize, vegetable pea, and sesbania showed markedly elevated levels of soil organic carbon (0.49%), bacterial populations (47.85 × 10^6 cfu/g soil), azotobacter populations (42.96 × 10^4 cfu/g soil), phosphate-solubilizing bacteria (20.72 × 10^6 cfu/g soil), dehydrogenase activity (4.39 µg TPF/g/h), fluorescein diacetate hydrolytic activity (17.28 µg fluorescein/g/h), acid phosphatase activity (451.46 µg pNP/g/h), and urease activity (47.21 µg NH4+/g/h) in comparison to the rice–wheat system. As a result, the incorporation of vegetables and legumes into cropping systems emerges as a feasible approach to enhance productivity, profitability, and soil health in the Eastern Gangetic Plains. Beillouin, et al (2021) opined that ecological theory asserts that biodiversity has a positive effect on and stabilizes the delivery of ecosystem services. Nevertheless, the implications of augmenting the diversity of cultivated crop species or varieties within agroecosystems continue to be a subject of active research. The available empirical evidence is varied in its breadth, agronomic methodologies, and geographical settings, with the effects on ecosystem services differing according to the particular diversification strategy utilized. To comprehensively assess the impacts of crop diversification in agroecosystems, we compiled results from 95 meta-analyses that included 5,156 experiments conducted over a span of 84 years, which featured more than 54,500 paired observations across 120 crop species in 85 nations. Our extensive analysis indicates that crop diversification not only increases crop yields (with a median effect of +14%) but also promotes associated biodiversity (+24%, which pertains to non-cultivated flora and fauna) and various supporting and regulating ecosystem services, such as water quality (+51%), pest and disease management (+63%), and soil quality (+11%). Importantly, there is significant variability in the results for each ecosystem service based on the diversification strategy applied, which may include agroforestry, intercropping, cover crops, crop rotation, or variety mixtures. Agroforestry is particularly notable for its effectiveness in delivering multiple ecosystem services, including water regulation and quality, pest and disease management, associated biodiversity, and sustained soil productivity and quality. Conversely, variety mixtures provide the least advantages, while the other strategies yield intermediate results. These findings highlight that enhancing the diversity of cultivated crop species or varieties in agroecosystems represents a viable strategy for achieving more sustainable land management, resulting in improved yields, increased biodiversity, and enhanced ecosystem services, although the efficacy of specific crop diversification strategies varies significantly. Tamburini, et al (2020) emphasized that practices of diversification are essential for improving biodiversity, pollination, pest control, nutrient cycling, soil health, and water management. It is advised that enhancing biodiversity within agricultural frameworks can promote ecosystem services, which may subsequently reduce dependence on agricultural inputs while ensuring high levels of crop productivity. This research assesses the impact of different diversification strategies in cropping systems on both aboveground and belowground biodiversity and ecosystem services by reviewing 98 meta-analyses and performing a second-order meta-analysis that encompasses 5,160 original studies with 41,946 comparisons between diversified and simplified practices. The results reveal that diversification has a positive effect on biodiversity, pollination, pest control, nutrient cycling, soil health, and water management, all while preserving crop yields. Strategies designed to boost aboveground biodiversity were especially effective in enhancing pest management and water regulation, while those aimed at belowground biodiversity improved nutrient cycling, soil health, and water management. Overall, diversification practices resulted in mutually advantageous outcomes for ecosystem services and crop yields. Nevertheless, the variability in responses and the existence of trade-offs highlight the significance of context in shaping results. The broad adoption of diversification practices presents considerable potential for promoting biodiversity conservation and securing food supply at both local and global scales.

Data Source and Methodology

The present study is based on secondary data which has been collected from the economic survey of Chhattisgarh for the year 2023-24. The major crops included in the study are rice, pulses, wheat, vegetables, fruits, flowers, oilseeds, plantations, species for all the 28 districts of Chhattisgarh.Further the districts were classified into agro climatic zones viz; Northern Hills, Plains of Chhattisgarh and Bastar Plateau.

The analysis of the data has been done in Advanced MS Excel 2016 version. Descriptive analysis has been done and then Simpson Index has been calculated for knowing the crop diversification in the three agro climatic zones of Chhattisgarh.

$$\text{Simpson Index: } D=\sum ni(ni-1)/N(N-1)$$

According to this index; value close to zero indicates diversification (richness) and value nearer to 1 indicates less diversification or specialization of crop.

Results and Discussions

The descriptive statistics for Rice, Pulses, Wheat, and Vegetables provide an overview of their distribution, variability, and central tendency. The data highlights key patterns in the production or usage of these commodities, reflecting variations in mean values, dispersion, and shape of the distribution.

Table 1: Results of Descriptive Statistics

Descriptive Statistics	Rice	Pulses	Wheat	Vegetables
Mean	395.8744	16.978	7.784929	246.1654
Standard Error	42.64996	5.71671	2.634509	30.17277
Standard Deviation	225.6824	30.24998	13.94051	159.6593
Kurtosis	1.495988	3.065631	14.405	2.904387
Skewness	0.994426	2.104898	3.495907	1.088923
Minimum	42.932	0.166	0	8.421
Maximum	1080.096	105.592	69.295	768.137
Count	28	28	28	28

*(**Source:** authors own calculation based on secondary data)*

The table no 1 depicts that the average values represent the typical levels for each commodity. Rice exhibits the highest average value at 395.87, indicating that it is produced or consumed in significantly greater amounts than the other commodities. Following rice, vegetables have an average of 246.17, which points to a moderately high level of production or consumption. In contrast, pulses and wheat show lower average values of 16.98 and 7.78, respectively, suggesting that their quantities in the dataset are relatively minimal.

The data's variability is assessed through standard deviation and standard error. Rice displays the highest standard deviation at 225.68, signifying considerable variation among its data points. This indicates a wide range of production or consumption levels across different observations. Vegetables also demonstrate notable variability, with a standard deviation of 159.66. Conversely, pulses and wheat have lower standard deviations of 30.25 and 13.94, respectively, suggesting more uniform levels in their datasets. The standard error, which indicates the accuracy of the mean, is greatest for rice at 42.65 and least for wheat at 2.63, suggesting that the average for wheat is estimated with the highest degree of precision.

Kurtosis and skewness values offer further insights into the distribution's characteristics. A kurtosis value exceeding 3 indicates a leptokurtic distribution (characterized by a sharp peak), while a value below 3 suggests a platykurtic distribution (with a flatter peak). Wheat has the highest kurtosis at 14.41, indicating a sharply peaked distribution with heavier tails, which implies the presence of extreme values in the dataset. Pulses (3.07) and vegetables (2.90) are closer to a leptokurtic distribution, whereas rice (1.49) exhibits a

flatter peak, indicating a wider spread around the mean. Skewness quantifies the asymmetry present in a dataset. A positive skewness indicates that the distribution has a longer tail on the right side. Wheat exhibits the highest skewness at 3.49, signifying a strong positive skew where a few high values significantly affect the overall data. Pulses (2.10) and Vegetables (1.09) also display positive skewness, albeit to a lesser extent, indicating moderate asymmetry. In contrast, Rice (0.99) shows the lowest skewness, suggesting that its data is relatively symmetrical when compared to the other commodities.

The range, derived from the minimum and maximum values, illustrates the extent of data variation. Rice has the broadest range, spanning from 42.93 to 1080.10, which indicates considerable variability. Vegetables also present a wide range (8.42 to 768.14), reflecting diverse levels among observations. Pulses (0.17 to 105.59) and Wheat (0 to 69.30) have narrower ranges, suggesting less extreme variations. Each dataset for the commodities consists of 28 observations, allowing for effective comparison. The differences in metrics such as mean and standard deviation highlight variations in scale and distribution, indicating that Rice and Vegetables exhibit broader and more variable patterns, while Pulses and Wheat show more localized and consistent trends.

In conclusion, the descriptive statistics indicate that Rice and Vegetables lead in average quantity and variability, whereas Pulses and Wheat present lower and more stable values. The skewness and kurtosis analysis reveals that Wheat possesses the most pronounced distribution characteristics, emphasizing the impact of outliers or high variability within its dataset.

The Crop Diversification Index (CDI) is a measure that indicates the extent of crop diversification in a region, with higher values reflecting greater diversity in cropping patterns. Chhattisgarh's agricultural landscape is characterized by its distinct agro-climatic zones: The Northern Hills, the Plains of Chhattisgarh, and the Bastar Plateau. Each zone exhibits unique cropping patterns influenced by factors such as topography, soil type, water availability, and socio-economic conditions.

Table 2: Crop Diversification Index(CDI) of Chhattisgarh

S.No.	Crops	Northern Hills	Plains of CG	Bastar Plateau
1	Rice	0.015	0.591	0.011
2	Wheat	0.021	0.719	-0.239
3	Pulses	0.004	0.829	0.0003
4	Vegetables	0.054	0.428	0.0124
5	Fruits	0.067	0.401	0.011
6	Flowers	0.052	0.506	0.002
7	Spices	0.074	0.341	0.019

*(**Source:** authors own calculation based on secondary data)*

Table 2 reveals the CDI for major crop categories across agro climatic zones, offering valuable insights into regional diversification trends and potential strategies for sustainable agricultural development.

Northern Hills: Low Crop Diversification Index (CDI) Across Most Cultivars

The Northern Hills, characterized by their rolling landscape and restricted irrigation options, show generally low CDI values for a majority of crops:

- **Rice:** The CDI of 0.015 signifies minimal cultivation, as rice farming is hindered by water scarcity and topographical limitations.
- **Wheat:** With a CDI of 0.021, wheat production is limited, likely due to unfavorable climatic conditions and soil properties.
- **Pulses:** The CDI for pulses is particularly low at 0.004, indicating a lack of movement towards leguminous crops, despite their compatibility with rainfed agriculture.

- **Vegetables, Fruits, and Flowers:** Moderate CDI values of 0.054 (vegetables), 0.067 (fruits), and 0.052 (flowers) imply some level of diversification, influenced by niche farming and opportunities for high-value crops.
- **Spices:** A CDI of 0.074, the highest among all crops in this area, indicates a rising interest in spice cultivation, which thrives under the region's agro-climatic conditions and market demand.

The Northern Hills demonstrate limited crop diversification, primarily due to climatic challenges and a dependence on traditional agricultural methods. Focused efforts to encourage the cultivation of pulses, spices, and high-value horticultural products could foster greater diversification and enhance farmers' income.

Plains of Chhattisgarh: High Crop Diversification Index for Major Crops

The Plains of Chhattisgarh, known for their rich soils and improved irrigation systems, demonstrate notable crop diversification across several categories:

- **Rice:** With a Crop Diversification Index (CDI) of 0.591, rice remains the predominant crop in the region, earning the title of the "Rice Bowl of India." However, this heavy dependence on paddy cultivation raises concerns regarding sustainability due to its high water requirements.
- **Wheat:** A CDI of 0.719 positions wheat as one of the leading crops, indicating favorable conditions for rabi season cultivation.
- **Pulses:** The CDI of 0.829 reflects a strong shift towards pulse farming, which benefits from drought resistance and offers significant nutritional value.
- **Vegetables and Fruits:** Moderate CDI scores of 0.428 for vegetables and 0.401 for fruits highlight the increasing role of horticulture as an additional income stream.
- **Flowers and Spices:** CDIs of 0.506 for flowers and 0.341 for spices suggest a move towards high-value crop production, often influenced by proximity to urban markets and demand from agro-industries.

The Plains showcase considerable crop diversification, facilitated by favorable agro-climatic conditions, enhanced infrastructure, and access to markets. Nonetheless, the prevailing dominance of rice necessitates the implementation of strategies to promote alternative crops such as pulses and vegetables, aiming to alleviate water stress and ensure sustainable agricultural practices in the long run.

Bastar Plateau: Limited Crop Diversification

The Bastar Plateau, primarily inhabited by tribal communities and characterized by its hilly landscape and dense forests, demonstrates a lack of crop diversification:

- **Rice:** The crop diversity index (CDI) for rice stands at 0.011, indicating minimal rice cultivation, likely due to the limited adoption of high-yield varieties and insufficient irrigation infrastructure.
- **Wheat:** With a negative CDI of -0.239, wheat cultivation is virtually non-existent and ill-suited to the region's climatic conditions.
- **Pulses:** The CDI for pulses is 0.0003, suggesting their near absence in local farming practices, highlighting an opportunity for promoting sustainable rainfed agriculture.
- **Vegetables and Fruits:** CDI values of 0.0124 for vegetables and 0.011 for fruits reflect minimal horticultural engagement, attributed to a lack of technical expertise and market connections.
- **Flowers and Spices:** CDIs of 0.002 for flowers and 0.019 for spices indicate that these crops are largely untapped, despite their potential in the region's agro-climatic context.

The Bastar Plateau's extremely low crop diversification is a result of subsistence farming practices and limited access to resources and markets. Tailoring agricultural programs to the needs of tribal communities and promoting the cultivation of spices and pulses could enhance sustainable agricultural practices.

Overall Trends and Implications

- **Regional Disparities:** The Chhattisgarh Plains exhibit the highest levels of crop diversification, supported by favorable conditions and improved market access. In contrast, the Northern Hills and Bastar Plateau show limited diversification, primarily due to geographical challenges and insufficient infrastructure.
- **Over-Reliance on Rice:** Rice is the predominant crop across all regions, especially in the Plains, where its CDI is notably high. This reliance on monoculture raises concerns about resource depletion and economic instability.
- **Potential for Diversification:** Pulses and spices present viable alternatives, particularly in rainfed regions such as the Northern Hills and Bastar Plateau.
- High-value crops like vegetables, fruits, and flowers hold immense potential for expanding diversification in the Plains and Northern Hills.

Recommendations for Enhancing Crop Diversification

- **Advocate for Drought-Resistant Crop Cultivation:** Promote the growth of pulses, millets, and oilseeds in areas reliant on rainfall to strengthen resilience and secure food supplies.
- **Enhance Market and Infrastructure Development:** Establish cold storage facilities, processing centers, and efficient supply chains to facilitate market access for high-value crops such as vegetables, fruits, and flowers.
- **Capacity Building and Education:** Provide training for farmers on contemporary methods for growing horticultural and spice crops, particularly in the Northern Hills and Bastar Plateau regions.
- **Policy Enhancement:** Broaden government procurement strategies to encompass pulses, millets, and spices in addition to traditional staples like rice and wheat.

CONCLUSIONS

The Crop Diversification Index reveals notable differences in agricultural diversification among the agro-climatic zones of Chhattisgarh. The Plains demonstrate considerable diversity, whereas the Northern Hills and Bastar Plateau fall short, predominantly depending on conventional farming methods. To tackle these regional imbalances, implementing focused interventions, improving infrastructure, and developing farmer-oriented policies can foster sustainable agricultural development and improve income stability for farmers in Chhattisgarh.

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