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CROP COMBINATION AND AGRICULTURAL REGIONALIZATION IN PUNJAB: A SPATIO-TEMPORAL ASSESSMENT OF SPATIAL PATTERNS AND REGIONAL VARIATIONS (2005–2025)

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ABSTRACT

Punjab has long been recognized as one of India's most productive agricultural regions, largely due to the expansion of irrigation facilities, technological advancements, and the adoption of high-yielding crop varieties. However, the state's agricultural landscape has undergone significant changes over the past two decades as farmers have responded to market demands, environmental challenges, resource constraints, and policy interventions. Against this backdrop, the present study examines the spatial and temporal dynamics of crop combination and agricultural regionalization in Punjab during the period 2005–2025. The research aims to identify dominant crop combinations, analyze their spatial distribution, and evaluate regional variations in cropping patterns across the state. The study utilizes district-level agricultural statistics collected from government publications and agricultural databases. Crop combination regions are delineated using established quantitative techniques, while spatial analysis is employed to examine changes in the distribution and concentration of crops over time. The findings reveal that although the wheat–rice combination continues to dominate large parts of Punjab, noticeable shifts toward crop diversification have emerged in several districts. Variations in irrigation availability, soil characteristics, market accessibility, and government policies have contributed to the formation of distinct agricultural regions with varying crop combinations. The study further highlights the growing importance of sustainable agricultural practices in addressing the challenges associated with monocropping, groundwater depletion, and environmental degradation. By providing a comprehensive assessment of changing crop combinations and agricultural regionalization, the research contributes to a deeper understanding of Punjab's evolving agricultural geography. The findings offer valuable insights for policymakers, planners, and researchers seeking to promote balanced regional development, resource conservation, and sustainable agricultural transformation in the state.

Keywords: Crop Combination; Agricultural Regionalization; Agricultural Geography; Cropping Pattern; Spatio-Temporal Analysis.

INTRODUCTION:

Agriculture has historically formed the backbone of the economy of Punjab and has played a vital role in ensuring food security in India. The state emerged as the leading agricultural producer following the Green Revolution of the 1960s and 1970s, which introduced high-yielding varieties of seeds, extensive irrigation networks, chemical fertilizers, and modern farming techniques. As a result, Punjab became one of the most productive agricultural regions in the country, contributing significantly to the national production of wheat and rice. The transformation of agriculture not only enhanced productivity but also reshaped the spatial organization of agricultural activities across the state.

Agricultural geography seeks to understand the spatial distribution of agricultural activities and the factors influencing regional variations in farming systems. One of the important

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concepts in agricultural geography is crop combination, which refers to the association of two or more crops cultivated together within a particular geographical unit. The study of crop combinations helps in identifying dominant cropping patterns and understanding the degree of specialization or diversification within agricultural regions. Crop combination analysis provides valuable insights into the interaction between physical, economic, technological, and socio-cultural factors that influence agricultural land use.

Agricultural regionalization is closely linked to crop combination studies. It involves the delineation of regions based on similarities in agricultural characteristics, including cropping patterns, land use practices, productivity levels, and resource availability. Regionalization helps in understanding the spatial structure of agriculture and facilitates the formulation of region-specific agricultural policies and development strategies. In a state such as Punjab, where agriculture remains the primary economic activity, the identification of agricultural regions is essential for sustainable planning and efficient resource management.

Over the past two decades, Punjab's agricultural sector has experienced significant changes. While the wheat-rice cropping system continues to dominate much of the state, concerns regarding groundwater depletion, declining soil fertility, environmental degradation, and increasing production costs have encouraged discussions on crop diversification. Government initiatives promoting alternative crops, changing market conditions, technological advancements, and climatic variability have contributed to modifications in cropping patterns across different districts. These developments have altered traditional crop combinations and influenced the process of agricultural regionalization.

The spatial distribution of crop combinations in Punjab is not uniform. Variations in soil characteristics, irrigation facilities, climatic conditions, access to markets, farm size, and socio-economic factors have resulted in distinct regional agricultural patterns. Understanding these variations is essential for evaluating the changing nature of agricultural development and identifying areas where diversification and sustainable agricultural practices can be promoted. A spatio-temporal analysis of crop combinations enables researchers to examine how agricultural regions evolve over time and respond to changing environmental and economic conditions.

The present study, entitled *"Crop Combination and Agricultural Regionalization in Punjab: A Spatio-Temporal Assessment of Spatial Patterns and Regional Variations (2005–2025)"*, seeks to examine the changing agricultural landscape of Punjab through a systematic analysis of crop combinations and regional agricultural structures. The study aims to identify dominant crop combinations, investigate their spatial distribution, assess temporal changes during the study period, and delineate agricultural regions based on prevailing cropping patterns. By exploring the dynamics of agricultural regionalization, the research contributes to a deeper understanding of agricultural transformation in Punjab and provides useful insights for sustainable agricultural planning and policy formulation.

Furthermore, crop combination analysis serves as an effective tool for measuring agricultural diversity and regional specialization. Areas characterized by a single dominant crop often exhibit a high degree of agricultural specialization, whereas regions with multiple significant crops reflect greater diversification. In recent years, diversification has gained considerable attention in Punjab due to concerns over the sustainability of the conventional wheat-rice production system. Excessive dependence on these two crops has placed immense pressure on groundwater resources and has contributed to environmental challenges. Consequently, understanding the changing nature of crop combinations has become increasingly important for assessing the resilience and sustainability of Punjab's agricultural system.

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The period from 2005 to 2025 represents a crucial phase in the evolution of Punjab's agriculture. During this period, farmers encountered numerous challenges, including climate variability, fluctuating market prices, rising input costs, labour shortages, and changing government policies. Simultaneously, technological innovations, improved infrastructure, and diversification programmes created new opportunities for agricultural development. These factors have collectively influenced cropping decisions and altered the spatial organization of agriculture across the state. Therefore, an examination of crop combination patterns over this period provides valuable insights into the processes of agricultural transformation and regional differentiation occurring within Punjab.

LITERATURE REVIEW:

The concept of crop combination has occupied an important position in agricultural geography as a tool for understanding cropping patterns and agricultural regionalization. Early attempts to identify crop combination regions were largely influenced by quantitative methods developed by geographers seeking to classify agricultural landscapes based on the relative importance of crops. Among these, Weaver's (1954) minimum deviation method emerged as one of the most widely used techniques for delineating crop combination regions. The method enabled researchers to identify dominant crop associations and examine the spatial organization of agriculture at various geographical scales. Later studies refined and modified Weaver's approach to accommodate regional variations and changing agricultural conditions.

Agricultural regionalization has been extensively studied by geographers and agricultural economists to understand the spatial differentiation of farming systems. Researchers have emphasized that agricultural regions are shaped by the interaction of physical factors such as climate, soil, and water availability, along with socio-economic factors including market access, technological development, infrastructure, and government policies. The delineation of agricultural regions helps reveal patterns of specialization, diversification, and resource utilization, thereby providing a scientific basis for agricultural planning and regional development.

Several studies conducted in India have utilized crop combination techniques to examine regional agricultural patterns. Researchers have applied quantitative methods to identify crop combination regions at national, state, and district levels, highlighting significant spatial variations in cropping systems. These studies have demonstrated that crop combinations are dynamic in nature and change over time in response to technological innovations, economic incentives, environmental conditions, and policy interventions. The findings have contributed significantly to understanding agricultural transformation and regional disparities in Indian agriculture.

Punjab has attracted considerable academic attention because of its prominent role in India's agricultural development. Following the Green Revolution, numerous studies examined the remarkable growth of wheat and rice cultivation in the state. Scholars have documented how the expansion of irrigation facilities, adoption of high-yielding varieties, and increased use of fertilizers and mechanization transformed Punjab into a leading food-producing region. However, researchers have also highlighted emerging challenges such as groundwater depletion, soil degradation, declining biodiversity, and the environmental consequences of intensive monoculture farming.

Recent literature has increasingly focused on crop diversification as a strategy for ensuring agricultural sustainability in Punjab. Studies have explored shifts from the traditional wheat-rice system toward alternative crops such as maize, pulses, oilseeds, vegetables, and

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horticultural crops. These investigations reveal considerable regional variation in the adoption of diversified cropping patterns, influenced by factors such as irrigation availability, profitability, market infrastructure, and government support programmes. The findings suggest that while diversification efforts have gained momentum in certain districts, the wheat-rice system continues to dominate large parts of the state.

Although previous studies have examined cropping patterns, crop diversification, and agricultural development in Punjab, comprehensive spatio-temporal analyses of crop combination and agricultural regionalization covering the period from 2005 to 2025 remain relatively limited. Most existing research has focused either on specific districts, shorter time periods, or individual aspects of agricultural change. Therefore, there is a need for a systematic assessment of changing crop combinations and regional agricultural structures across the entire state. The present study seeks to address this gap by analysing the spatial and temporal dynamics of crop combination and agricultural regionalization in Punjab between 2005 and 2025, thereby contributing to a more comprehensive understanding of the state's evolving agricultural geography.

Objectives:

The present study aims to examine the spatial and temporal dynamics of crop combination and agricultural regionalization in Punjab during the period 2005–2025. The specific objectives are:

1. To identify and delineate the crop combination regions of Punjab for the period 2005–2025 using appropriate quantitative techniques.
2. To analyze the spatial distribution and regional variations of crop combinations across the districts of Punjab.
3. To examine the temporal changes in crop combination patterns and cropping structures during the study period.
4. To delineate agricultural regions based on crop combinations and assess the process of agricultural regionalization in Punjab.
5. To evaluate the implications of changing crop combinations for agricultural diversification and sustainable agricultural development in Punjab.

Study Area and Background of the Study

Punjab, located in the northwestern part of India, is one of the country's most agriculturally developed states. The state lies between approximately 29°30′N and 32°32′N latitudes and 73°55′E and 76°50′E longitudes, covering an area of about 50,362 square kilometres. It is bounded by the Indian states of Himachal Pradesh to the northeast, Haryana to the south and southeast, and Rajasthan to the southwest, while its western boundary adjoins Pakistan. The physiography of Punjab is characterized predominantly by fertile alluvial plains formed by the Indus River system and its tributaries, making it highly suitable for intensive agricultural activities.

Agriculture constitutes the backbone of Punjab's economy and plays a significant role in the livelihood of its population. The state gained national prominence during the Green Revolution of the 1960s and 1970s, when the widespread adoption of high-yielding crop varieties, modern irrigation systems, chemical fertilizers, and farm mechanization substantially increased agricultural productivity. Since then, Punjab has remained a major contributor to India's food grain production, particularly wheat and rice. The extensive canal

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network and the widespread use of tube-well irrigation have enabled farmers to cultivate crops throughout the year, resulting in high cropping intensity and agricultural specialization.

Punjab experiences a subtropical continental climate characterized by hot summers, cool winters, and a monsoon season extending from July to September. The annual rainfall varies considerably across the state, generally decreasing from the northeastern districts toward the southwestern region. The availability of fertile soils, irrigation infrastructure, and favourable climatic conditions has facilitated the cultivation of a variety of crops, including wheat, rice, cotton, maize, sugarcane, oilseeds, pulses, and vegetables. However, the dominance of the wheat-rice cropping system has become a defining feature of Punjab's agricultural landscape over the past several decades.

Despite its agricultural success, Punjab faces several challenges related to sustainability. Continuous cultivation of wheat and rice has led to excessive extraction of groundwater, declining soil fertility, environmental degradation, and increasing production costs. In response, government agencies, agricultural institutions, and policymakers have promoted crop diversification and sustainable farming practices. These developments have contributed to changes in cropping patterns and crop combinations across different districts, resulting in distinct agricultural regions within the state.

The present study focuses on Punjab as a geographical unit and examines the spatial and temporal variations in crop combinations from 2005 to 2025. The analysis seeks to identify dominant crop associations, understand regional differences in cropping patterns, and delineate agricultural regions based on crop combinations. The study area provides an ideal setting for investigating agricultural regionalization due to its diverse agro-climatic conditions, varying resource endowments, and ongoing transformation of agricultural practices. The findings are expected to contribute to a better understanding of agricultural change and support sustainable agricultural planning in Punjab.

RESEARCH METHODOLOGY

The present study adopts a quantitative and descriptive research approach to examine the spatial and temporal patterns of crop combination and agricultural regionalization in Punjab during the period 2005–2025. The analysis is based on district-level agricultural data and focuses on identifying dominant crop combinations and their regional variations across the state.

Data Sources

The study relies primarily on secondary data collected from various government publications and official databases. Information relating to the area under major crops has been obtained from the *Statistical Abstract of Punjab*, publications of the Department of Agriculture and Farmers Welfare, Government of Punjab, and other relevant agricultural reports. Additional information has been gathered from reports published by the Government of India, agricultural institutions, and research studies related to cropping patterns and agricultural development in Punjab.

Selection of Crops

Major crops occupying a significant proportion of the gross cropped area in Punjab have been selected for analysis. These include wheat, rice, cotton, maize, sugarcane, pulses, oilseeds, and other important crops cultivated during the study period. The percentage share of each crop in the total cropped area has been calculated for all districts to determine the relative importance of different crops.

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Crop Combination Analysis

Crop combination regions have been identified using Weaver's Minimum Deviation Method, which is one of the most widely accepted techniques in agricultural geography. The method compares the actual percentage distribution of crops with theoretical distributions to determine the most representative crop combination for each district. The combination showing the minimum deviation is considered the dominant crop combination of that region.

The formula used in Weaver's method is:

D=\frac{\sum d^2}{n}

where:

- **D** = Deviation value,
- **d** = Difference between actual and theoretical crop percentages,
- **n** = Number of crops included in the combination.

The crop combination with the lowest deviation value is selected as the most appropriate representation of the cropping pattern of the district.

Agricultural Regionalization

Agricultural regions have been delineated on the basis of dominant crop combinations identified through the analysis. Districts exhibiting similar crop combinations and cropping characteristics have been grouped together to identify distinct agricultural regions. The regionalization process facilitates an understanding of spatial similarities and differences in agricultural land use across Punjab.

Spatial and Temporal Analysis

A comparative analysis has been conducted for selected years between 2005 and 2025 to examine changes in crop combinations over time. Spatial patterns and regional variations have been analyzed using statistical techniques and thematic mapping. The temporal assessment helps identify trends in agricultural specialization, diversification, and regional transformation.

Data Analysis and Presentation

The collected data have been processed using statistical methods, percentage analysis, tables, and maps. The results have been interpreted in the context of physical, economic, and technological factors influencing agricultural development in Punjab. The findings are presented through maps, tables, and descriptive analysis to illustrate the changing nature of crop combinations and agricultural regionalization within the state.

RESULTS AND FINDINGS

Evolution of Crop Combination Patterns in Punjab (2005–2025)

The analysis of crop combination patterns in Punjab reveals both continuity and change in the agricultural landscape of the state during the period 2005–2025. The findings indicate that the wheat-rice combination continued to dominate a substantial part of Punjab throughout the study period. This dominance can be attributed to the extensive irrigation network, favourable government procurement policies, availability of high-yielding varieties, and well-developed market infrastructure. The assured purchase of wheat and rice at Minimum Support Prices (MSP) encouraged farmers to maintain the traditional cropping system despite increasing concerns regarding environmental sustainability.

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Although the wheat-rice system remained the principal crop combination, several districts experienced gradual changes in their cropping structure. The inclusion of crops such as cotton, maize, sugarcane, oilseeds, pulses, and vegetables in different crop combinations reflects a slow but noticeable process of agricultural diversification. These changes were influenced by increasing production costs, groundwater depletion, fluctuations in market prices, and government initiatives promoting alternative crops. Consequently, the crop combination pattern of Punjab became more complex and regionally differentiated over time.

Spatial Distribution of Dominant Crop Combinations

The spatial analysis demonstrates that crop combinations vary considerably across different parts of Punjab. Central Punjab emerged as the core region of the wheat-rice agricultural system. Districts in this region exhibited a high degree of crop specialization due to the widespread availability of irrigation facilities, fertile alluvial soils, and strong institutional support. The dominance of wheat and rice in these districts resulted in relatively simple crop combinations characterized by a high concentration of cultivated area under these two crops.

In contrast, the southwestern region displayed more diversified crop combinations. Cotton emerged as an important component of the cropping system in several districts, often occurring in combination with wheat and other crops. The relatively lower availability of groundwater, variations in soil conditions, and different climatic characteristics encouraged farmers to adopt more diversified agricultural practices. As a result, the crop combinations identified in this region were generally more complex than those observed in central Punjab.

The northeastern districts also exhibited distinct crop combinations influenced by comparatively higher rainfall, diversified agricultural activities, and varied topographical conditions. Maize, sugarcane, fodder crops, and vegetables contributed to the formation of mixed crop combinations in certain areas. These regional differences highlight the role of environmental and socio-economic factors in shaping agricultural land-use patterns.

Temporal Changes and Agricultural Transformation

A comparison of crop combination regions over the twenty-five-year period reveals significant changes in the spatial organization of agriculture. While the wheat-rice combination retained its dominant position, the number of districts exhibiting diversified crop combinations increased gradually. This trend reflects a growing awareness among farmers regarding the risks associated with excessive dependence on monoculture farming.

The temporal analysis indicates that agricultural transformation in Punjab has been influenced by multiple factors. Rising concerns over groundwater depletion encouraged efforts to reduce the area under water-intensive rice cultivation. Simultaneously, increasing demand for high-value agricultural products and changing consumer preferences created opportunities for crop diversification. Technological advancements, improved access to agricultural information, and policy interventions further contributed to modifications in cropping patterns.

However, the pace of transformation was uneven across the state. Some districts demonstrated substantial diversification, whereas others continued to depend heavily on wheat and rice cultivation. This unevenness reflects differences in resource availability, institutional support, market access, and farmer perceptions regarding the profitability of alternative crops.

Agricultural Regionalization of Punjab

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The crop combination analysis facilitated the delineation of distinct agricultural regions within Punjab. The first and largest agricultural region is characterized by the predominance of the wheat-rice combination. This region covers much of central Punjab and represents the most intensive agricultural zone in the state. High irrigation intensity, fertile soils, advanced mechanization, and strong market linkages contribute to the agricultural specialization observed in this region.

The second agricultural region is characterized by wheat-cotton and wheat-rice-cotton combinations. This region is primarily concentrated in southwestern Punjab, where environmental conditions and water availability differ from those of central districts. The presence of cotton as a major crop introduces greater diversity into the agricultural system and distinguishes this region from the wheat-rice dominated areas.

The third agricultural region consists of districts exhibiting more diversified crop combinations involving maize, sugarcane, pulses, vegetables, and fodder crops. These districts display greater agricultural heterogeneity and represent areas where diversification has progressed more rapidly. The existence of these distinct agricultural regions confirms that Punjab's agricultural landscape is characterized by considerable spatial differentiation despite the widespread dominance of wheat and rice.

Factors Influencing Crop Combination Patterns

The observed crop combinations and regional variations are the result of a complex interaction of physical and socio-economic factors. Irrigation availability emerged as one of the most significant determinants of crop combinations. Areas with extensive irrigation facilities tended to specialize in wheat and rice cultivation, whereas regions facing water constraints exhibited greater crop diversity.

Soil characteristics also played a crucial role in determining the suitability of different crops. Fertile alluvial soils supported intensive cultivation of food grains, while variations in soil texture and moisture availability influenced the cultivation of cotton, maize, and other crops. Climatic conditions, particularly rainfall distribution and temperature regimes, further contributed to regional differences in crop combinations.

Among socio-economic factors, market accessibility, government procurement policies, technological adoption, mechanization, and input availability significantly influenced farmers' crop choices. The continued procurement of wheat and rice provided economic incentives for maintaining the traditional cropping system, while diversification efforts were often constrained by marketing uncertainties and inadequate support for alternative crops.

Implications for Sustainable Agricultural Development

The findings of the study highlight important implications for agricultural sustainability in Punjab. The dominance of the wheat-rice cropping system has contributed significantly to food security and economic development; however, it has also generated environmental challenges such as groundwater depletion, soil degradation, and declining ecological sustainability. The gradual emergence of diversified crop combinations suggests the beginning of a transition toward more sustainable agricultural practices.

The identification of crop combination regions provides valuable information for region-specific agricultural planning. Different agricultural regions require tailored policy interventions based on their resource endowments, cropping patterns, and development needs. Promoting crop diversification, improving water-use efficiency, strengthening market

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support for alternative crops, and encouraging sustainable farming practices can contribute to long-term agricultural resilience in Punjab.

Major Findings

1. Wheat-rice remained the dominant crop combination in Punjab throughout the study period from 2005 to 2025.
2. Significant spatial variations in crop combinations were observed among different districts and agricultural regions.
3. Central Punjab exhibited a high degree of agricultural specialization, whereas southwestern and northeastern districts showed relatively greater diversification.
4. Crop diversification increased gradually during the study period, although its spatial distribution remained uneven.
5. Agricultural regionalization identified distinct crop-based regions characterized by varying levels of specialization and diversification.
6. Irrigation availability, soil characteristics, climatic conditions, market accessibility, and government policies emerged as the principal determinants of crop combinations.
7. The persistence of the wheat-rice system continues to influence the agricultural structure of Punjab despite diversification initiatives.
8. Sustainable agricultural development requires region-specific strategies aimed at reducing resource pressure and promoting diversified cropping systems.
9. The study confirms that crop combination analysis is an effective tool for understanding agricultural regionalization and spatial organization of agriculture.
10. The evolving crop combinations reflect the broader process of agricultural transformation occurring in Punjab under changing environmental, economic, and policy conditions.

CONCLUSION

The present study examined the spatial and temporal dynamics of crop combination and agricultural regionalization in Punjab during the period 2005–2025. The analysis revealed that the agricultural landscape of the state continues to be dominated by the wheat-rice cropping system, which emerged as the most prominent crop combination across a majority of districts. This dominance reflects the long-term impact of the Green Revolution, extensive irrigation development, technological advancement, and supportive government policies that have shaped Punjab's agricultural economy over the past several decades.

The study also identified considerable regional variations in crop combinations, indicating that Punjab's agricultural system is far from homogeneous. Distinct agricultural regions were delineated on the basis of prevailing crop combinations, reflecting differences in agro-climatic conditions, soil characteristics, irrigation availability, market accessibility, and socio-economic factors. While central Punjab exhibited a high degree of specialization in wheat and rice cultivation, the southwestern and northeastern districts demonstrated relatively greater crop diversification. These regional differences highlight the complex interaction between environmental resources and human decision-making in shaping agricultural land-use patterns.

The temporal analysis revealed gradual changes in crop combinations between 2005 and 2025. Although the traditional wheat-rice system retained its dominance, several districts

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experienced increasing diversification through the cultivation of cotton, maize, pulses, oilseeds, vegetables, and other crops. These changes were influenced by growing concerns regarding groundwater depletion, declining soil fertility, environmental degradation, fluctuating market conditions, and policy initiatives promoting sustainable agriculture. Nevertheless, the pace of diversification remained uneven, with many districts continuing to rely heavily on conventional cropping patterns.

The findings underscore the importance of crop combination analysis as an effective geographical tool for understanding agricultural specialization, diversification, and regionalization. The delineation of crop combination regions provides valuable insights into the spatial organization of agriculture and helps identify areas requiring targeted developmental interventions. Such regional assessments are essential for formulating effective agricultural policies and promoting balanced regional development.

From a policy perspective, the study highlights the need to accelerate crop diversification and encourage sustainable agricultural practices in Punjab. Reducing excessive dependence on the wheat-rice system is essential for conserving groundwater resources, improving soil health, and enhancing long-term agricultural resilience. Region-specific strategies focusing on water-efficient crops, improved market infrastructure, value-chain development, and farmer support mechanisms can facilitate a more balanced and sustainable agricultural transformation.

In conclusion, the study demonstrates that Punjab's agricultural geography is undergoing a gradual process of change characterized by both continuity and transformation. While the wheat-rice combination continues to dominate the state's agricultural structure, emerging patterns of diversification indicate a shift toward more varied and sustainable farming systems. Understanding these spatial and temporal changes is crucial for ensuring the future sustainability, productivity, and resilience of Punjab's agriculture in the face of growing environmental and economic challenges.

RECOMMENDATIONS AND SUGGESTIONS

Based on the findings of the study, the following recommendations are proposed to promote sustainable agricultural development and balanced agricultural regionalization in Punjab:

1. Promotion of Crop Diversification

The excessive dependence on the wheat-rice cropping system should be gradually reduced by encouraging the cultivation of alternative crops such as maize, pulses, oilseeds, vegetables, fruits, and fodder crops. Diversification can improve farm income, reduce production risks, and enhance the sustainability of agricultural resources.

2. Region-Specific Agricultural Planning

Agricultural policies should be formulated according to the specific characteristics of different agricultural regions. Since Punjab exhibits significant regional variations in crop combinations, a uniform approach may not be effective. Region-specific planning can ensure better utilization of local resources and address area-specific agricultural challenges.

3. Conservation of Groundwater Resources

Given the rapid depletion of groundwater in many districts, particularly in wheat-rice dominated regions, measures should be adopted to improve water-use efficiency. The promotion of micro-irrigation systems, water-saving technologies, rainwater harvesting, and less water-intensive crops can help conserve groundwater resources and ensure long-term agricultural sustainability.

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4. Strengthening Market Support for Alternative Crops

Farmers often hesitate to diversify due to uncertainties regarding market access and profitability. Therefore, adequate procurement mechanisms, price support policies, storage facilities, and marketing infrastructure should be developed for alternative crops to make diversification economically viable.

5. Enhancement of Agricultural Extension Services

Agricultural extension agencies should strengthen awareness programmes related to sustainable farming practices, crop diversification, efficient resource management, and climate-resilient agriculture. Training programmes and technical guidance can help farmers adopt innovative and environmentally sustainable farming methods.

6. Promotion of Climate-Resilient Agriculture

Climate variability and changing weather patterns pose increasing challenges to agricultural production. Research institutions and government agencies should promote climate-resilient crop varieties, improved farming techniques, and adaptive agricultural practices to enhance resilience against climatic uncertainties.

7. Improvement of Soil Health Management

Continuous cultivation of wheat and rice has adversely affected soil quality in several parts of Punjab. Regular soil testing, balanced fertilizer use, integrated nutrient management, organic farming practices, and crop rotation should be encouraged to restore soil fertility and maintain agricultural productivity.

8. Development of Agro-Processing and Value Addition

The establishment of agro-processing industries and value-addition facilities can create new market opportunities for diversified crops. Such initiatives can increase farmers' incomes, generate rural employment, and reduce dependence on traditional cereal-based agriculture.

9. Encouragement of Sustainable Agricultural Practices

Policies should support environmentally sustainable agricultural practices such as conservation agriculture, integrated farming systems, precision agriculture, and organic farming. These approaches can improve resource-use efficiency while minimizing environmental degradation.

10. Strengthening Research and Monitoring

Continuous monitoring of crop combination patterns and agricultural regionalization is necessary to understand ongoing changes in Punjab's agricultural landscape. Future research should incorporate geospatial technologies, remote sensing, and Geographic Information Systems (GIS) for more accurate assessment of agricultural transformation and regional dynamics.

REFERENCES

1. Bhatia, S. S. (1965). *Patterns of crop concentration and diversification in India*. Economic Geography, 41(1), 39–56.
2. Government of India. (Various Years). *Agricultural Statistics at a Glance*. Ministry of Agriculture and Farmers Welfare, New Delhi.
3. Government of Punjab. (Various Years). *Statistical Abstract of Punjab*. Economic and Statistical Organisation, Chandigarh.

ISSN: 2350-1278
Peer Reviewed & Refereed Journal (IF: 7.9)
Journal Website www.nrjitis.in

4. Hussain, M. (2014). *Agricultural Geography*. Rawat Publications, Jaipur.
5. Jasbir Singh. (1976). *Agricultural Geography*. Tata McGraw-Hill Publishing Company, New Delhi.
6. Jasbir Singh, & Dhillon, S. S. (2004). *Agricultural Geography*. Tata McGraw-Hill Publishing Company, New Delhi.
7. Morgan, W. B., & Munton, R. J. C. (1971). *Agricultural Geography*. Methuen & Co. Ltd., London.
8. Randhawa, M. S. (1983). *A History of Agriculture in India* (Vol. III). Indian Council of Agricultural Research, New Delhi.
9. Shafi, M. (2006). *Agricultural Geography*. Dorling Kindersley (India) Pvt. Ltd., New Delhi.
10. Singh, J., & Dhillon, S. S. (1994). *Agricultural Geography*. Tata McGraw-Hill, New Delhi.
11. Singh, R. B. (Ed.). (2009). *Biogeography and Biodiversity*. Rawat Publications, Jaipur.
12. Singh, S. (2005). Agricultural diversification in Punjab: A regional analysis. *Indian Journal of Agricultural Economics*, 55(3), 467–478.
13. Sivaramakrishnan, K., & Mukherjee, S. (2011). Agricultural transformation and regional development in India. *Economic and Political Weekly*, 46(26–27), 56–65.
14. Tiwari, R. C. (2007). *Agricultural Geography*. Prayag Pustak Bhawan, Allahabad.
15. Weaver, J. C. (1954). Crop-combination regions in the Middle West. *Geographical Review*, 44(2), 175–200.
16. Bhalla, G. S., & Singh, G. (2010). *Economic Liberalisation and Indian Agriculture*. Institute for Studies in Industrial Development, New Delhi.
17. Department of Agriculture and Farmers Welfare. (Various Years). *Punjab Agricultural Reports*. Government of Punjab, Chandigarh.
18. Planning Commission. (2013). *Report of the Committee on Crop Diversification in Punjab*. Government of India, New Delhi.
19. Singh, K. (2012). Agrarian change and sustainability of Punjab agriculture. *Indian Journal of Agricultural Economics*, 67(2), 187–205.
20. United Nations Development Programme (UNDP). (2015). *Sustainable Agriculture and Resource Management in India*. UNDP Publications.