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Original Article

Spatial Analysis of Typologies and Dynamics of Crop Combination Regions of Kaushambi District, Uttar Pradesh, India

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Abstract *- The spatial analysis of crop combination regions is a vital aspect of agricultural geography, aiming to understand the distribution, classification, and evolution of cropping patterns across space and time. This study explores the fundamental concepts and meanings associated with the typologies and dynamics of crop combination regions. Typologies refer to the systematic classification of areas based on recurring combinations of crops, offering insights into regional agricultural structures and farming systems. Meanwhile, dynamics denote these combinations' temporal and spatial shifts, influenced by many factors, including climate variability, soil conditions, market demand, technological advancements, and policy interventions. The present research aims to identify patterns, trends, and anomalies in cropping systems by employing spatial analysis techniques such as GIS mapping, quantitative indices (e.g., Weaver's 'Minimum Deviation Technique'), and statistical modelling of block-wise data in the decade of 2000-01 and 2020-21 of Kaushambi district. This analysis reveals significant spatial disparities in crop combination patterns, with regions transitioning from traditional foodgrain dominance to more diversified and commercial crop mixes due to changes in irrigation infrastructure, market accessibility, and agricultural policy interventions. The findings underscore the dynamic nature of cropping systems and highlight zones of mono-cropping vulnerability and multi-cropping potential. This research not only enhances the geographical understanding of agricultural land use but also provides valuable insights for sustainable agricultural planning, resource optimisation, crop diversification strategies, policy formulation, rural development, and regional planning of the study area. This study will contribute to regional development discourse by integrating spatial and temporal dimensions in analysing crop combination regions, offering a comprehensive approach to understanding agricultural transformations for the ecological suitability and socio-economic needs of the Kaushambi district.*

Keywords *- Agriculture Typology, Crop Combination and Region, Dynamics of Crop Combination, Cropping Pattern, Sustainable Agriculture Planning.*

1. Introduction

Agriculture is one of the most important primary human activities as it forms a significant share of human and animal food as well as other materials to meet human needs, including the need for industrial raw materials (Andrabi, 2019). It is a spatially and temporally dynamic activity with diverse cropping patterns across different geographical regions. Agricultural development is a multidimensional concept that includes a variety of aspects such as classification of land use, crop concentration and diversification, crop productivity, commercial attributes of agriculture, intensity of cropping, maintenance of ecological balance and so on (Tiwari & Sharma, 2013). Studying crop combinations is important in agricultural geography because it provides a strong basis for agricultural regionalisation. Crop combination refers to the most prominent group of crops grown in a region during a particular period. The spatial analysis of typologies and dynamics of crop combination regions offers a comprehensive understanding of agricultural land-use patterns. Analysing these regions through a spatial lens enables researchers to explore where specific crop combinations occur, why such patterns emerge, and how they evolve. Spatial analysis involves the examination of geographic data to identify patterns, relationships, and variations across regions. Applied to crop combinations, it helps delineate distinct agricultural zones, detect clustering of specific crop types, and reveal the influence of physical, climatic and socio-economic factors. Spatial and temporal patterns of crop combinations provide know-how for the contemporary and changing patterns of inter-crop struggle (Modhave & Markad, 2017). The term typologies of crop combinations refers to the classification of regions based on the nature and intensity of crop diversity. Such typologies provide valuable insights into the complexity of land use, regional food systems, and the adaptability of agricultural practices. On the other hand, the dynamics of crop combinations refer to the changes in cropping patterns over time, which are driven by factors such as market shifts, environmental change, technological adoption, and policy reforms.

Crops are generally grown in combination, and complete domination by a single crop in a given area at any

time is rare (Thakur, 2007). Such a study of crops provides approaches for agricultural regionalisation based on agriculture's nature, method and characteristics. At the same time, appropriate suggestions can be given to solve the current agricultural problems. The distribution of various crops and their growth depends upon physio-socio-economic conditions and adaptation of innovation in agriculture, i.e., the use of high-yielding varieties, improved and efficient implements, and applications of chemical fertilisers and pesticides (Modhave & Markad, 2017).

The group of major crops grown in a region or area is called a crop combination. In the study of agricultural regionalisation and the regional research of crop patterns or forms, crop combination is also necessary. With this, the regional characteristics of agriculture can be easily identified. Therefore, crop combination regions are determined based on the spatial dominance of those crops in which regional correlation is found and are grown simultaneously in different forms. Such a study of crops provides approaches for agricultural regionalisation based on the nature, method and characteristics of agriculture, whereby appropriate suggestions can be given for solving the current agricultural problems.

Together, the spatial analysis of typologies and dynamics of crop combination regions offers a comprehensive understanding of agricultural land-use patterns. This integrated perspective is essential for formulating region-specific agricultural policies, promoting sustainable farming practices, and enhancing food security through optimised land resource utilisation.

2. Literature Review

Various national and international scholars have tried to study and regionalise crop combinations. Literature of some of the prominent scholars has been reviewed: Firstly, in 1954, J.C. Weaver used a statistical method in the crop combination region of the mid-west United States of America. He gave a new direction to the crop study and created a mathematical model for determining crop combinations. P. Scott (1957) has adopted the modified form of Weaver's method while classifying the crop combination region of Tasmania. He has used Mr. Weaver's method to determine specific crops. Along with major crops, other crops and animal husbandry have also been combined. B.L.C. Johnson (1958) has divided East Pakistan (Bangladesh) into crop combination regions based on the relative importance of crops. He has adopted a simple scale of gradation in determining crop combinations.

Based on the importance scale of the five crops in the study area, he classified the region into five levels: highest, high, medium, low, and minimum. Kikukazu Doi (1959) modified Weaver's technique to discover Japan's industrial structure. Its theoretical basis is economic, like Weaver's. Doi also assumed that the cultivated land was equally distributed among all crops. Like Weaver, the difference between theoretical and actual percentages has also been determined. Thomas (1963) modified Mr. Weaver's method of finding the deviation. Weaver calculated the difference between the two main crops in the two-crop combination. In contrast, Thomas calculated the difference between the actual and theoretical percentages for all crops in each crop combination.

In India, R.K. Banerjee (1963) used Weaver's modified method to divide West Bengal into crop combination regions for the first time. S.M. Rafiullah (1965) has adopted the maximum positive deviation method for determining crop combinations. N.P. Iyer (1969) has divided the 43 districts of Madhya Pradesh into three crop combinations and nine crop combination regions. He has adopted the 'Maximum Distance Method' for determining crop combinations. Various popular studies have been done by different scholars in various areas of the country, i.g., Punjab Plain by Harpal Singh (1963) and Eastern Ganga-Ghaghara Doab by B.K. Rai (1967), Luni Basin by Ahmad and Siddiqui, Bundelkhand region by Siddiqui, Lower Ganga-Yamuna Doab by Tripathi and Miss Agarwal, North Bihar by B. Mandal (1969). The studies on Uttar Pradesh, Majid by S. C. Sharma (1971), crop combination region of Uttar Pradesh by Hussain, Chhattisgarh basin by P.R. Sharma (1972), Eastern India by S.C. Chakraborty (1981), Andhra Pradesh by Ramaniya and Reddy (1968) and crop combination of Nainital district (Uttar Pradesh) by J.C. Kuniyal (1988) are especially noteworthy.

S.A. Khan (1982), F.M. Siddiqui (1968), V.R. Singh and R.S. Chandel (1991), K.S. Sohal (1993), Todkari (2012), Tiwari and Sharma (2013), Patil (2017), Rashinkar (2018), Gaikwad (2019), Kank (2022), Praveen (2023), etc., scholars have studied and analysed the crop combination during a specific time.

Kaushambi, a predominantly agrarian district in the fertile Indo-Gangetic plain, displays various crop combinations influenced by varying physical, socio-economic, and technological factors. Despite a growing literature on crop combination studies, there remains a notable gap in spatially detailed and timely dynamic analysis of crop combination regions at the block level, especially in understudied and agricultural transition regions such as the Kaushambi district of Uttar Pradesh. Most previous studies have either focused on broad regional scales (state or national level) or employed traditional methods of crop combination analysis without integrating advanced geospatial techniques and temporal datasets.

Moreover, existing studies rarely consider agricultural infrastructure, market access, local demand, nutrition and sustainability in furthering the spatial diversity of crop combinations. There is an inadequate understanding of how agricultural policies, land use change, and socio-economic transition reshape crop patterns and combinations in economically backward districts such as Kaushambi. Integration of remote sensing, GIS tools, and spatial statistics for identifying and analysing crop combination types is still underutilised in this context.

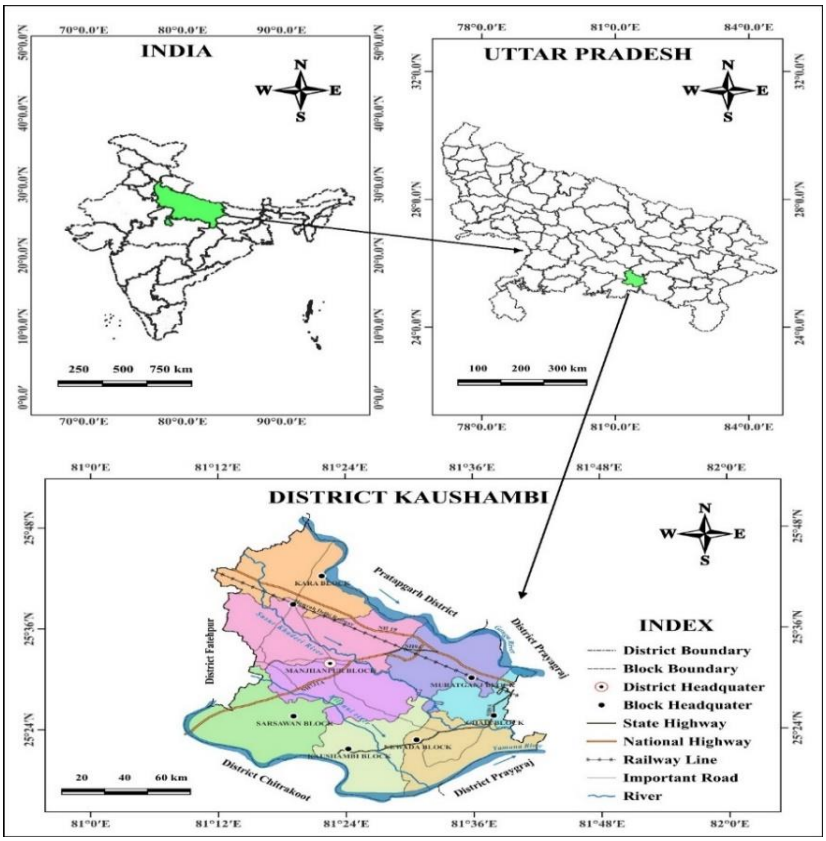
2.1. Objective

- To analyse crop combinations' spatial and temporal dynamics through clustering using GIS tools and statistical methods.
- To identify the circumstances and factors influencing the changes and suggest measures for developing region-specific recommendations for improving agricultural productivity and sustainability based on spatial and dynamic analyses of crop combinations.

2.2. Data Sources and Methodology

The present study is based on secondary data, which has been obtained from the District Statistical Handbook, District Kaushambi, Uttar Pradesh. Apart from this, map-related data has been obtained from the Survey of India. MS Office has been used for data analysis, and ArcGIS 10.2 software has been used to create maps. Crop combination has been studied block-wise in the years 2000-01 and 2020-21, and changes in crop combination have also been studied. Weaver's 'Minimum Deviation Method' (1954) has been adopted to study crop combinations. The theoretical basis of Weaver's technique is that agricultural land is equally engaged under all crops. For example, if there is only one crop in an area, it is in 100% of the area. Suppose there are two crops, and 50% of the area is included under each. If there are three crops, each should have 33.3% of the area; if there are 10 crops, each should have a 10% cultivated area. First, the percentage of land under various crops from the gross crop area in each development block has been determined and arranged in descending order. In the calculation of crop combination, such crops whose area is less than 1 percent of the total crop area have not been included. After this, the square of the difference between the land under crop and the theoretical percentage has been calculated, and all of them have been added and divided by the number of crops. In this order, the crops with the minimum deviation value have been placed in the crop combination. It is necessary to clarify here that Weaver's objective was not to find out the actual amount of deviation by the standard deviation method but to find out the relative rank of the deviation. In calculating crop combination, the formula of variance $\sigma^2=\sum d^2/n$ has been used instead of the deviation formula. Here, 'd' means the difference between the crop's theoretical and actual areas, and 'n' means the number of crops in the crop combination.

Weaver's minimum deviation method is used for crop combination analysis because this method has statistical impartiality, objectivity, transparency, simplicity and broad applicability. It provides a quantitative and reproducible approach to classify crop areas based on the actual area under cultivation. This method is easy to apply with limited data, making it suitable for micro and macro field studies. Unlike more straightforward rank-based or descriptive methods, it considers exact crop area percentages, providing better spatial resolution. Its statistical rigour reduces subjectivity. The accuracy and flexibility make it a widely accepted and reliable technique for analysing spatial agricultural situations compared to other methods.



Source: Survey of India & Census of India

Fig. 1 Location of Kaushambi District, Uttar Pradesh, India

2.3. Limitations

The present study has some limitations. The study depends on secondary data, and the analysis is based on only two decadal years (2000-01 and 2020-21), which do not include the short-term changes. The study does not include crops with less than 1% of the area. Although direct farmer surveys or interviews have not been conducted, farmers' inputs have been added based on field-level trends, observations, discussions, nutrition needs and existing literature.

2.4. The Study Area

Kaushambi is a district of the Indian state of Uttar Pradesh, renowned as a historical and religious city. It emerged as a new district on 4 April 1997 by separating it from Prayagraj and incorporating three tehsils: Sirathu, Manjhanpur and Chail. Manjhanpur is the headquarters of the district.

District Kaushambi is located in the southeastern part of Uttar Pradesh, whose latitudinal extension is between 25°15' and 25°47' north latitude. Longitudinal extension is between 81°12' and 81°47' east longitude. It is spread over a geographical area of 1,779 square km (Fig.1). The study area is located in the lower Ganga-Yamuna Doab, on whose northern border the river Ganga flows, forming its natural boundary. In contrast, the river Yamuna determines its natural boundary in the south. On a political basis, the district has been divided into three tehsils- Manjhanpur, Sirathu and Chail, and the tehsils have been divided into eight development blocks. Manjhanpur tehsil has Sarsawan, Manjhanpur and Kaushambi; Sirathu tehsil has Kada and Sirathu; Chail tehsil has Chail, Muratganj and Newada development blocks. The total population of the district is 15,99,596 (2011) persons. The population density of the Kaushambi district is 899 persons km², and the decadal growth rate is 23.7%.

3. Results and Discussion

3.1. Crop Combination in the District

After analysing crop combinations in the study area using Weaver's minimum deviation method, researchers found that the farmers adopted various combinations according to their economic needs and physical circumstances. The area under different crops, block-wise in the district in the decade of 2000-01 and 2020-21, is shown in Tables 1 and 2, respectively. Analysing the combination of the crops in the study area is shown in Tables 3 & 4 and Fig. 2. Symbolic expressions of crop combinations. In the Kaushambi district, a combination of 2 crops to 8 crops is found block-wise.

3.1.1. Monoculture & Two-Crop Combination

The district Kaushambi is located in the plains of the Ganga Yamuna Doab, where fertile alluvial soil is mainly found, which allows crops to be grown in all three seasons of Rabi, Kharif, and Zaid. Monoculture is not seen in any development block of the Kaushambi district from 2000 to 01 and from 2020 to 21.

Table 1. Percentage of Cropped Area of Kaushambi district, U.P. (2000-01)

Sr. no	Blocks	Crops								
		Wheat	Rice	Pulses	Millets	Barley	Vegetables	Commercial Crops	Fodder	Oilseeds
1	Kara	43.41	11.6	15.24	16.89	3.05	5.15	0.22	1.02	3.43
2	Sirathu	41.93	12.9	16.87	18.95	1.93	3.17	1.5	1.1	1.64
3	Sarsawan	27.69	24.66	19.96	15.67	3.05	1.57	5.5	1.13	0.78
4	Manjhanpur	37.41	28.7	13.41	12.22	2.67	1.99	1.31	0.92	1.37
5	Kaushambi	32.29	24.8	18.63	15.33	3.68	1.3	1.68	1.46	0.84
6	Muratganj	40.81	15.48	19.09	16.29	5.32	1.13	0.2	1.17	0.52
7	Chail	28.9	22.76	18.56	19.83	5.3	1.05	0.53	2.26	0.81
8	Newada	39.61	11.78	20.13	18.62	5.47	1.64	0.9	1.48	0.37

Source: Calculated from the Statistical Handbook of Kaushambi District (2002)

Table 2. Percentage of Cropped Area of Kaushambi district, U.P. (2020-21)

Sr. no	Blocks	Crops								
		Wheat	Rice	Pulses	Millets	Barley	Vegetables	Commercial Crops	Fodder	Oilseeds
1	Kara	39.65	25.91	11.12	8.46	0.64	10.7	0.1	0.79	2.64
2	Sirathu	42.54	28.68	13.44	6.29	0.46	5.85	0.28	0.68	1.78
3	Sarsawan	37.23	28.88	14.99	7.61	1.38	6.28	0.43	0.76	2.45
4	Manjhanpur	38.83	34.54	8.41	8.55	0.44	6.85	0.21	0.75	1.43
5	Kaushambi	38.82	28.5	14.58	8.26	1.08	4.9	0.46	1.3	2.11
6	Muratganj	50.38	22.17	7.75	7.8	0.31	8.07	0.15	2.14	1.23
7	Chail	37.92	27.98	11.16	7.73	0.25	10.09	0.56	3.16	1.15
8	Newada	48.75	22.7	10.74	4.57	0.34	7.84	0.94	3.08	1.05

Source: Calculated from the Statistical Handbook of Kaushambi District (2022)

Similarly, in 2000-01, the combination of two crops is not seen in any development block, whereas in 2020-21, the combination of two crops, wheat and rice, is found only in the Manjhanpur development block. Due to the development of adequate irrigation facilities in recent times, high specialisation of crops has occurred in the Manjhanpur development block.

3.1.2. Three & Four Crop Combination

In 2000-01, the combination of three crops is not seen in any development block, whereas in 2020-21, the combination of three crops is seen in Sirathu, Sarsawan and Kaushambi development blocks and wheat, rice and pulses are the first, second and third-ranked crops respectively in all the three development blocks. In 2000-01, except for the Kada development block, the combination of four crops is seen in all other development blocks, but there is a difference in their ranking order. In the Sirathu development block, wheat, millets, pulses and rice are first, second, third and fourth rank crops, respectively; in Sarsawan, Manjhanpur and Kaushambi, wheat, rice, pulses and millets are first, second, third and fourth rank crops, respectively, similarly in Muratganj and Newada wheat, pulses, millets and rice are first, second, third and fourth rank crops respectively whereas in Chail, wheat, rice, millets and pulses are first, second, third and fourth rank crops respectively. In 2020-21, no four crop combinations were received in any development block of the district.

Table 3. Delineation of Crop Combination Pattern of Kaushambi District, U.P.

Sr.no	Blocks	Year 2000-01			Year 2020-21		
		Values	Crop Combinations	Type of Crops	Values	Crop Combinations	Type of Crops
1	Kara	167.55	8	W+M+P+R+V+O+B+F	143.91	5	W+R+P+V+M
2	Sirathu	133.93	4	W+M+P+R	167.39	3	W+R+P
3	Sarsawan	29.95	4	W+R+P+M	123.83	3	W+R+P
4	Manjhanpur	116.34	4	W+R+P+M	181.89	2	W+R
5	Kaushambi	46.82	4	W+R+P+M	135.05	3	W+R+P
6	Muratganj	112.84	4	W+P+M+R	258.05	7	W+R+V+M+P+F+O
7	Chail	22.11	4	W+R+M+P	142.34	5	W+R+P+V+M
8	Newada	113.16	4	W+P+M+R	243.85	7	W+R+P+V+M+F+O

*Note: W=Wheat, R=Rice, P=Pulses, M=Millets, B=Barley, V=Vegetables, C=Commercial Crops, F=Fodder, O=Oilseeds

Source: Calculated by the author

Table 4. Crop Combination Pattern in Kaushambi, U.P. 2000-01 & 2020-21

Sr. no.	No. of Crops	Year 2000-01		Year 2020-21	
		No. of Blocks	Name of blocks	No. of Blocks	Name of Blocks
1	Monoculture	0	-	0	-
2	2 Crops	0	-	1	Manjhanpur
3	3 Crops	0	-	3	Sirathu, Sarsawan, Kaushambi
4	4 Crops	7	Sirathu, Sarsawan, Manjhanpur, Kaushambi, Muratganj, Chail, Newada	0	-
5	5 Crops	0	-	2	Kada, Chail
6	6 Crops	0	-		-
7	7 Crops	0	-	2	Muratganj, Newada
8	8 Crops	1	Kada	0	-

Source: Calculated by the author

3.1.3. Five & Six Crop Combination

In 2000-01, the combination of five crops was not seen in any development block, whereas in 2020-21, the combination of five crops was found in two development blocks, Kada and Chail. Wheat, rice, pulses, vegetables, and millet are the first, second, third, fourth, and fifth-rank crops in Kada and Chail development blocks. In 2000-01, the combination of six crops was not seen in any development block; similarly, in 2020-21, the combination of six crops was not found in any development block.

3.1.4. Seven & Eight Crop Combination

In 2000-01, the combination of seven crops was not seen in any development block, whereas in 2020-21, the combination of seven crops was seen in Muratganj and Newada development blocks. In 2020-21, in the Muratganj development block, wheat, rice, vegetables, millets, pulses, fodder and oilseeds are the first, second, third, fourth, fifth, sixth and seventh-ranked crops, respectively, whereas in the Newada development block, wheat, rice, pulses, vegetables, millets, fodder, and oilseeds are the first, second, third, fourth, fifth, sixth and seventh-ranked crops respectively. From 2000 to 01, the eight crops were combined only in the Kada development block. In 2000-01, in the Kada development block, wheat, millets, pulses, rice, vegetables, oilseeds, barley and fodder were the first, second, third, fourth, fifth, sixth, seventh and eighth-ranked crops, respectively. In 2020-21, the combination of eight crops was not seen in any development block.

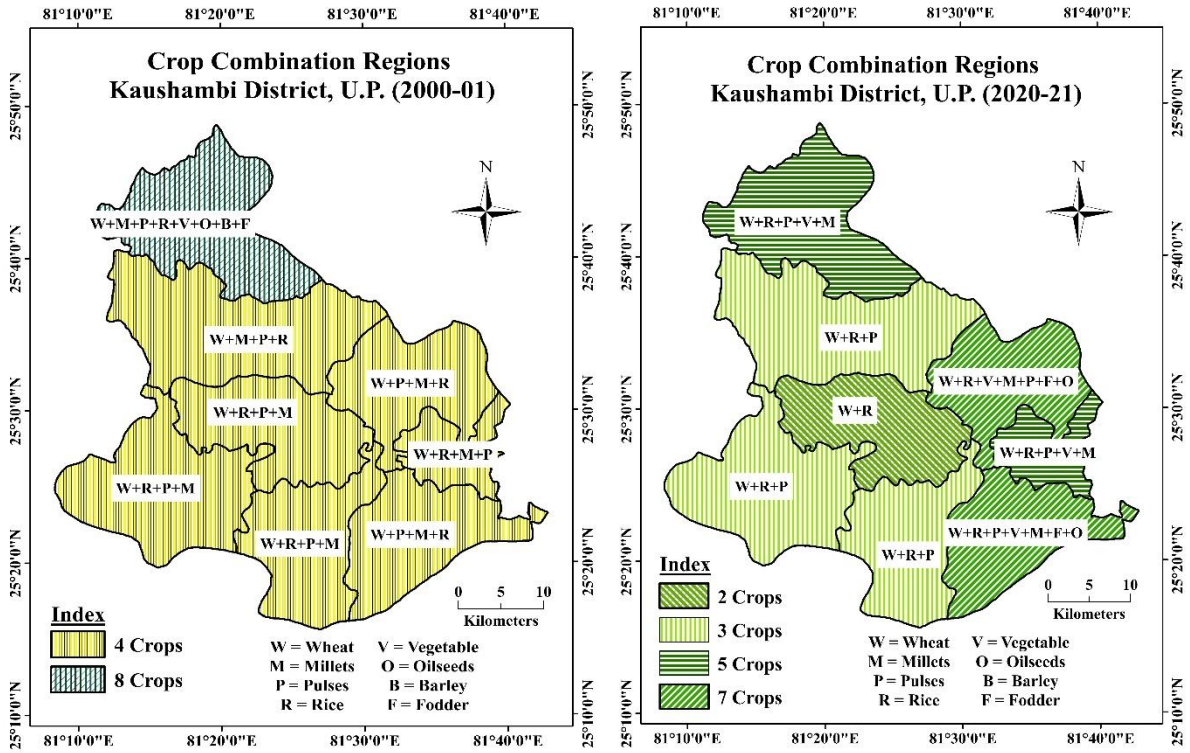


Fig. 2 Crop Combination Pattern in Kaushambi District, U.P. (2000-01 & 2020-21)
Source: Calculated from the Statistical Handbook of Kaushambi District (2002&2022)

3.2. Dynamics of Crop Combination

Significant changes have been recorded in the crop combination block-wise in the Kaushambi district. In the year 2000-01, the best combination of eight crops of the district was obtained in the Kada development block, which included wheat, millets, pulses, rice, vegetables, oilseeds, barley and fodder crops, whereas in 2020-21, it was reduced to five crop combinations, which included wheat, rice, pulses, vegetables and millets. In recent years, it has been excluded from the crop combination due to a lack of sufficient production area for barley in all the development blocks, including the Kada development block. Similarly, the production area of fodder and oilseed crops has also been reduced. In the year 2000-01, four crop combinations were obtained in the Sirathu development block, which included wheat, millets, pulses and rice crops, whereas in 2020-21, it was reduced to three crop combinations, which included wheat, rice and pulses. As a result of an increase in irrigation facilities in the district and a change in food habits, the production area of millets is continuously decreasing in almost all the development blocks, due to which it is getting out of the crop combination. The same is the situation of the Sarsawan development block, where in the year 2000-01, four crop combinations were achieved, which included wheat, rice, pulses and millets crops, whereas, in 2020-21, it was reduced to three crop combinations, which included wheat, rice and pulses crops. In the year 2000-01, four crop combinations were achieved in the Manjhanpur development block, which included wheat, rice, pulses and millet crops, whereas in 2020-21, it was reduced to two crop combinations, which included wheat and rice. In 2020-21, the maximum specialisation is seen in the Manjhanpur development block, where, due to a decrease in the production area of millets and pulses, it has been excluded from the crop combination. Similarly, in the Kaushambi development block, four crop combinations were achieved in the year 2000-01, which included wheat, rice, pulses and millet crops, whereas in 2020-21, it was reduced to three crop combinations, which included only wheat, rice and pulses.

In the year 2000-01, four crop combinations were achieved in the Muratganj development block, which included wheat, pulses, millets and rice crops, whereas in 2020-21, it increased to seven crop combinations, which include wheat, rice, vegetables, millets, pulses, fodder and oilseeds crops. There has been an improvement in the crop combination in Muratganj; such an improvement is necessary for balanced development. Similarly, in the Chail development block, four crop combinations were achieved in the year 2000-01, which included wheat, rice, millets and pulses crops, whereas in 2020-21, it increased to five crop combinations, which include wheat, rice, pulses, vegetables and millets crops. In the year 2000-01, four crop combinations were achieved in the Newada development block, which included wheat, pulses, millets and rice crops, while in 2020-21, it increased to seven crop combinations, which include wheat, rice, pulses, vegetables, millets, fodder and oilseed crops. In Chail, Muratganj and Newada, all three are adjacent to Prayagraj city, due to which the demand for vegetables has been high here in recent years; as a result, due to the increase in the production area, vegetables have made an important place in crop

combination in the year 2020-21 in all three development blocks.

4. Conclusion and Suggestions for Sustainable Management

Generally, it is seen that wheat is the main crop of the district, which has been the first category crop during the years 2000-01 to 2020-21; along with this, in recent years, a substantial increase has been registered in the area under rice in almost all the development blocks, as a result of which rice has become the second main crop. In 2020-21, the rice crop is included in the crop combination as a second-rank crop in all the development blocks. A decrease in pulses has been recorded in all the development blocks in the district from 2000-01 to 2020-21. In the year 2000-01, pulse crops were included in the crop combination in all the development blocks, whereas in the year 2020-21, pulse crops were not included in the crop combination of the Sarsawan development block. During the years 2000-01 to 2020-21, there has been a drastic reduction in the area of millets in all the development blocks, as a result of which it has been left out of the crop combination in four development blocks, Sirathu, Sarsawan, Manjhanpur and Kaushambi. Apart from this, there has been a decline in its rank in all the other development blocks. The area of commercial crops is significantly less in all the development blocks in the district, resulting in no place for the crop combination. The same is the case with fodder and oilseed crops. In 2000-01, fodder and oilseed crops had a place in the crop combination only of the Kada development block, whereas in 2020-21, fodder and oilseed crops had a place in the crop combination in two development blocks, Muratganj and Newada. These crops have no place in the crop combination of other development blocks. With the increase in wheat crop, the production of barley in the district kept on decreasing continuously; in the year 2000-01, it got a place in the crop combination only in the Kada development block, whereas in 2020-21, barley did not get a place in the crop combination in any development block.

There is a need to adopt such a crop combination in the study area, where pulses and oilseeds are included in the crop combination, along with food crops and commercial crops, including vegetables, should also be included in the combination. Apart from this, coarse grains and fodder crops should also be included in the combination. An increase in wheat and rice is suitable for feeding the population. At the same time, a lack of pulse crops and coarse grains is a problem for food balance and the availability of nutrition. Pulses and oilseeds contribute significantly to maintaining natural productivity by providing specific nutrition for human health and balancing the soil's nutrition. Growing coarse grains provides fodder for animals along with grains. Similarly, growing pulse crops helps fix nitrogen in the soil, which maintains the fertility of the land. Managed crop combinations provide food nutrition, food security, land use efficiency, soil fertility, economic improvement and environmental sustainability of the district. Therefore, there is a need to include these crops in the combination of all development blocks. There is a need to promote commercial crops in the district so that farmers will get more income and self-reliance will increase. There is a need for further improvement in fodder crops so that animal husbandry, animal health and nutrition remain good. In this way, by adopting balanced crop combinations and crop diversification, positive improvements can be made in food balance, human development, and environmental conditions.

Farmers preferred wheat and rice for better procurement prices and assured government support under MSP. The decline in pulses and millets is mainly due to poor market linkages and a lack of government incentives. Many farmers observed declining soil fertility due to the monoculture of the wheat-rice cycle and excessive use of chemical fertilisers. Despite interest in sustainable farming, awareness of and access to organic inputs or bio-fertilisers are limited. Uneven irrigation facilities affect crop selection. Irrigated areas prefer wheat and rice, while rain-fed areas are moving away from traditional crops like millet. Farmers cited erratic rainfall and increased vulnerability to extreme weather events, discouraging the cultivation of sensitive crops like pulses and vegetables. There is growing interest in climate-resilient varieties, but availability and extension support are limited. Labour shortage and rising costs are pushing farmers towards less labour-intensive crops. Small and marginal farmers cannot access machinery, which restricts diversification.

Implement targeted schemes and subsidies to revive declining crops such as pulses and millets, essential for soil health and dietary balance. It should develop market-linked support for vegetables and commercial crops to increase farmer incomes and reduce dependency on traditional cereal-dominated systems. Policy implementers may promote crop rotation and inter-cropping practices to increase soil fertility, reduce dependence on chemical fertilisers, and align with climate-resilient agricultural strategies in the district. Make soil health cards mandatory and link subsidy benefits to soil-based crop recommendations. The government can start training and extension programs for farmers on crop diversification, sustainable practices, and the benefits of government schemes. It should motivate an effort to prepare and implement the agro-climatic zone-wise crop planning to recommend suitable crops, promote widespread use of green manure, organic farming, and bio-fertilisers, and support dual-purpose crops that provide grain and fodder in the study area. Moreover, adopting appropriate crop combinations and sustainable management is essential for achieving rural development, ensuring food security, and protecting ecological systems. It aligns with global goals like SDG 2 (Zero Hunger) and SDG 13 (Climate Action).

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