Geo-spatial Assessment of Cropping Pattern Dynamics in Arid and Semi-Arid Regions: A Case Study of Mashi Command Area, Rajasthan (India)

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Abstract

Due to gigantic food demand and climate alteration over the past few decades cropping pattern has been changing at the arid semi-arid regions across the world such as India. Cropping pattern study has played a significant role in balancing the increasing demand for food along with sustainable agriculture management. In this context, geo-spatial technology and mapping offers an extensive information about the agriculture lands and determine the land use planning to the current and predicted scenario for policy makers. In the present study, to depict the cropping pattern, we were used few statistical methods namely trend and distribution of major crops, cropping intensity, crop diversification, and crop yield index in the Mashi command area, Rajasthan, India. For this geo-spatial assessment, Rabi and Kharif crop census data sheet was used from 1987-89 to 2017-19. To assessment the cropping intensity and crop diversification, percentage ratio and Bhatia's (1965) method were used. For the crop yield index, Yang's (1965) method was used. The trend analysis reveals that out of the 14 crops, 02 crops have rapidly rising trends, 03 crops are stable, while 09 crops have a rapid decreasing trend at the command area villages. Cropping intensity also showing the fluctuations across the command area villages spanning from 1987-89 to 2017-19. The observed patterns of cropping intensity suggest shifts in agricultural practices and land use dynamics over the specified time periods. The crop diversification patterns reflect dynamic shifts in agricultural practices. The crop yield results highlight the dynamic nature of crop productivity in the study area. The proposed work provides a scientific approach to monitor and management of cropping pattern at the arid semi-arid regions across the globally regions.

Keywords: Cropping pattern, Geo-spatial technology, arid and semi-arid region, Rajasthan (India).

1 Introduction

1.1 Overview of cropping pattern

The agricultural sector is a cornerstone of India's economy, vital for livelihoods and significantly contributing to the nation's socio-economic GDP. It sustains rural communities and ensures food security while driving economic growth and stability through substantial contributions to India's GDP. The cropping pattern of a region reflects its geographical, climatic, socio-cultural, economic, historical, and political dynamics (Pande & Deshmukh 2015). This practice involves growing different crop types in a specific sequence or rotation, essential for maintaining soil health, maximizing yields, and reducing risks associated with monoculture. India's diverse physical geography and agro-climatic conditions support the cultivation of a variety of crops, leading to three primary crop seasons: Kharif, Rabi, and Zaid, each differing in crop varieties, sowing time, harvesting time, and rainfall patterns (Mondal et al., 2014; Khan and Ahmad, 2019). This diversity underscores the multifaceted nature of India's agricultural landscape and the dynamic nature of crop cultivation over time.

- **Kharif Season:** The Kharif season starts with the onset of the southwest monsoon in June and last September. This season is known for its long-duration crops that require high rainfall, warm weather, and a long growing season. The major crops grown during this season include paddy, maize, jowar, bajra, tur, moong, urad, cotton, and groundnut. The sowing of Kharif crops starts in June, and harvesting takes place between September and October. The Kharif season contributes to around 50% of the total food grain production in India.
- **Rabi Season:** The Rabi season starts from October and last March. This season is characterized by crops that require relatively low rainfall and a cooler climate. The major crops grown during this season include wheat, barley, gram, mustard, taramira, and oilseed. The sowing of Rabi crops starts in October and November, and harvesting takes place between March and April. The Rabi season contributes to around 30% of the total food grain production in India.
- **Zaid Season:** The Zaid season is a short-duration crop season that starts from March and last June. This season is characterized by crops that require a warm climate and less water. The major crops grown during this season include watermelon, muskmelon, cucumber, bitter gourd, pumpkin, and vegetables like chilly, tomato, brinjal, and potato etc. The sowing of Zaid crops starts in March, and harvesting takes place between May and June. The Zaid season contributes to around 5% of the total food grain production in India.

1.2 Types of cropping pattern

The choice of cropping pattern depends on several factors, namely the farmer's goals, local climate, soil conditions, and market demands. A well-planned and systematic cropping pattern helps to farmers to achieve sustainable and profitable agriculture in addition to preserving the health of the soil (Feder and Umali, 1993). Some common cropping patterns are shown in Table 1.

Table 1 Cropping patterns with advantage and disadvantage

Cropping Pattern	Description	Advantages	Disadvantages
Monoculture	Growing a single crop on a piece of land over multiple seasons.	Optimizes inputs and specialization in a particular crop.	Can lead to soil degradation and pest infestations over time.
Crop rotation	Growing different crops on a piece of land in a specific sequence, typically in a 2- or 3-year cycle.	Improves soil fertility, reduces pest and disease pressure, and diversifies farm income.	Requires careful planning and management.
Intercropping	Growing two or more crops simultaneously on the same piece of land.	Maximizes land use efficiency, and can be interdependent, with one crop providing support or protection to the other.	Requires careful selection of compatible crops and management.
Agroforestry	Growing trees or shrubs alongside crops on the same piece of land.	Improves soil health, reduces erosion, provides shade and shelter to crops, and generates additional income from timber and other forest products.	Requires careful selection of tree and crop species and management.
Alley cropping	Planting rows of trees or shrubs in between rows of crops.	Provides shade, reduces wind erosion, and contributes to soil fertility, while the crops benefit from reduced competition for nutrients and water.	Requires careful selection of tree and crop species, and management.

Source: Feder and Umali, 1993

1.3 Factors affecting cropping pattern

Cropping patterns in a region are shaped by a range of natural and human-made factors. Soil type and climatic conditions are vital in determining suitable crops; sandy soils are ideal for well-drained crops, whereas clay soils retain more water. Rainfall, temperature, and humidity levels greatly influence crop selection; rice thrives in high rainfall, while wheat tolerates drier conditions. Water availability, including irrigation systems, dictates crop choices; regions with ample water resources support water-intensive crops like paddy, while arid areas are suitable for low-water crops like millets. Land size impacts cropping patterns, with smaller farms limited in labour-intensive crops. Market demand, government policies, and technological advancements also influence crop selection. Changes in water access and soil degradation can alter cropping patterns. Understanding these factors is vital for farmers and policymakers to ensure sustainable agriculture and food security (Sridharan and Radhakrishnan, 1978).

1.4 Importance of cropping pattern study along with geo-spatial technology

Cropping pattern change study plays a pivotal role in understanding the evolving dynamics of agricultural systems over time, guiding informed decision-making, and ensuring sustainable agricultural practices (Akhtar & Acharya 2015). This comprehensive analysis provides valuable insights into the effects of cropping pattern changes on agricultural landscapes, as well as the strategies to enhance agricultural sustainability and productivity. The key points from the provided information are as follows:

Understanding Agricultural Dynamics: The study of cropping pattern changes offers a perception into the dynamics of agricultural systems and their evolution over time, providing a foundation for informed decision-making.

Informed Decision Making: It aids decision makers, researchers, and farmers in making well-informed decisions about land use, crop selection, and resource management by identifying trends in cropping patterns.

Identification of Drivers of Change: By pinpointing the drivers of change, including biophysical and socio-economic factors, the study enables the development of targeted interventions to address specific challenges and opportunities within agricultural systems.

Sharing Best Practices: It identifies best practices and success stories from different regions, facilitating their sharing and replication in other areas to accelerate the adoption of sustainable and productive agricultural practices.

Impact on Agriculture Land and Livelihoods: Understanding the impacts of cropping patterns on agricultural land is important for ensuring food security and sustainable livelihoods for farmers and rural communities.

Role of Geographic Information System (GIS): GIS technology has emerged as a powerful tool for analysing cropping pattern changes in a geospatial manner, enabling the integration of data from various sources to provide a comprehensive and accurate picture of the agricultural landscape.

Geo-Spatial Analysis: The chapter showcases the geo-spatial analysis of cropping patterns at the Mashi command area, offering a systematic examination of cropping patterns and suggesting targeted measures to improve agricultural productivity and sustainability.

This analysis, conducted using advanced geospatial tools such as Geographic Information System (GIS) and ArcGIS software, underscores the significance of studying cropping pattern changes and the vital role it plays in ensuring the sustainable and efficient utilization of agricultural resources. The primary objectives of the study are as follows:

- To examine the area under major crops using statistical analysis from 1987-89 to 2017-19
- To examine the trend of individual crop using trend analysis from 1987-89 to 2017-19
- To examine the spatial pattern of cropping intensity from 1987-89 to 2017-19
- To examine the spatial pattern of crop diversification index using Bhatia's method from 1987-89 to 2017-19
- To examine the spatial pattern of crop yield index using Yang's methods from 1987-89 to 2017-19

2 Materials and Methods

2.1 Data collection

The analysis of cropping patterns was conducted using secondary datasets, including Milan Khasra (involving Village geographical Area, Net Sown Area, and Gross Cropped Area), Siyalo data sheet (providing Village-wise Kharif crop data), and Unhalo data sheet (containing Village-wise Rabi crop data) gathered at the village level. These datasets were acquired from the land revenue department in Tehsil Peeplu and the Department of Economics and Statistics in Tonk, Rajasthan. Data on the average crop yield area at both village and tehsil levels was sourced from the revenue department in Peeplu Tehsil and the Department of Economics and Statistics in Tonk District. The main focus of this study centres around 14 key seasonal crops (both Kharif and Rabi) across a period of three decades, spanning from 1987-89 to 2017-19.

2.2 Data processing

Data processing is a vital and necessary stage in obtaining structured and precise findings from any research endeavor. Initially, the data underwent a cleaning process, which entailed the removal of errors, disparities, and missing data points. Subsequently, the data was structured appropriately and modified to enhance its suitability for statistical evaluation. Various statistical metrics pertaining to crop analysis, including crop combinations, cropping intensity, crop concentration, crop yield index, and crop diversification index, were employed to conduct a geospatial examination of cropping patterns within the Mashi command region. The outcomes of this analysis were visually represented using software tools such as ArcGIS 10.8, facilitating easier comprehension and communication. Statistical graphs were generated using the data analysis tool Excel 2016, while ArcGIS was specifically utilized for mapping the spatial and temporal aspects of cropping patterns within the designated study area.

2.3 Village for cropping pattern study

A total of 38 villages out of the 126 in the Peeplu tehsil were carefully chosen to be the focus of observation regarding cropping patterns within and around the Mashi command area, utilizing a set of distinct criteria. Initially, priority was given to villages with a larger gross cultivated area. Furthermore, villages were selected based on the presence or absence of canal facilities for irrigation. Emphasis was placed on villages grappling with salinity and land degradation issues, given their substantial impact on land productivity. Inclusion of villages near dam sites was also a key consideration, attributed to the influence of water and soil moisture levels on cropping patterns. Moreover, villages in close proximity to rivers were included due to the availability of high-quality water, which directly affects crop selection. Following the selection of villages based on these criteria, the predominant crops cultivated in each village were identified, and the cultivated area for each crop was quantified.

2.4 Cropping pattern analysis methods

The following methods were used to find out the cropping pattern in the study area from 1987-89 to 2017-19.

2.4.1 Cropping Intensity

Cropping intensity is a percentage ratio of gross cropped area and net sown area which refers to the number of crops grown on a field during an agriculture year. The cropping intensity was calculated using the following formula (Eq. 1):

$$\boldsymbol{Crop\ Intensity} = \frac{\boldsymbol{Gross\ Cropped\ Area}}{\boldsymbol{Net\ Sown\ Area}} * \mathbf{100} \qquad \text{Eq. 1}$$

Where:
Gross cropped area is the total area of all crops or total harvested cropped area in a year.
Net cropped area or Net sown area is the total land for sowing and harvesting.

2.4.2 Crop Diversification Index

Bhatia's (1965), crop diversification index was used to examine the diversity of crops in the study region. This index measures the percentage of net sown area under a certain number of crops. The crop diversification index was calculated using the following formula (Eq. 2):

$$\textit{Index of Crop diversification} = \frac{\textit{Percentage of sown area under x crops}}{\textit{Number of x crops}} * 100 \qquad \text{Eq. 2}$$

Where:
Area under x = x crops are those occupy 10 per cent or more of the gross cropped area
x = number of crops

2.4.3 Crop Yield Index or Agriculture Productivity

The Crop Yield Index (CYI) method was used to analyse the relative productivity of crops in study regions. It is used to compare the yields of crops in different regions, and to identify regions with high or low productivity. The yield index for each region is calculated by dividing the average yield for that region by the overall average yield for the crop across all regions (Yang, 1965). The CYI was calculated using the following formula (Eq. 3):

$$\text{Yang's } \textit{Crop yield index} = \frac{Y}{Y_n} \div \frac{T}{T_n} \qquad \text{Eq. 3}$$

Where:
Y = Total production of selected crops in unit area
Yn = Total production of same selected crops at national level
T = Total cropped area of the unit
Tn = Total cropped area at national scale

3 Results and Discussion

3.1 Distribution of major crops

The spatial distribution of major crops in the Mashi Command Area, Peeplu, has been highly variable. The study investigated the distribution of 14 major crops, which included kharif crops namely Jowar, Bajra, Groundnut, Maize, Chilly, Moong, Sesame, Urad, Kharif Vegetables, and in rabi crops like Barley, Mustard, Wheat, Gram, and Taramira. In the CMD area, food crops, oilseed crops, fodder crops and pulses predominantly occupy agricultural land. The distribution of food crops aligns with the physical environment and the dietary preferences of the local community. Wheat, bajra, and barley are the primary food grains grown, serving as staples for the area's residents. Additionally, jowar and maize are main fodder crops in this region. Among pulses, moong, urad, and gram dominate, while in the oilseeds category mustard, groundnut, and Sesame are the main crops cultivated. The performance of these crops shows significant fluctuations. Table 2 and figure 1 & 2 clearly illustrates that during the kharif season, bajra and jowar are primary food crops, whereas wheat takes precedence in the rabi season. Mustard emerges as the dominant oilseed crop in the CMD area. The village-wise distribution of major crops provides useful information for farmers and policymakers, to identify the crops that are best suited for their area and crop selection.

Table 2 Area under major crops from 1987-89 to 2017-19(Area in hectare %)

Major Crops	1987-89	Area in %	1997-99	Area in %	2007-09	Area in %	2017-19	Area in %
Kh. Jowar	9204	15.34	5490	11.00	4755	9.24	6104	10.58
Kh. Bajra	5448	9.08	2724	5.46	3724	7.24	3765	6.52
Kh. Groundnut	1668	2.78	1992	3.99	606	1.18	315	0.55
Kh. Maize	1296	2.16	852	1.71	655	1.27	356	0.62
Kh. Chilly	2199	3.66	1308	2.62	506	0.98	204	0.35
Kh-Moong	7740	12.90	2784	5.58	3945	7.67	2944	5.10
Kh-Sesame	1845	3.07	732	1.47	3986	7.75	1462	2.53
Kh-Urad	2556	4.26	4956	9.93	4324	8.40	6631	11.49
Kh-Vegetables	906	1.51	798	1.60	501	0.97	686	1.19
Rb. Barley	3324	5.54	780	1.56	560	1.09	448	0.78
Rb. Mustard	6105	10.17	18144	36.36	22478	43.68	29593	51.27
Rb. Wheat	11196	18.66	7374	14.78	3964	7.70	4052	7.02
Rb. Gram	6192	10.32	1764	3.54	803	1.56	832	1.44
Rb. Taramira	323	0.54	198	0.40	653	1.27	326	0.56
Total	60002	100	49896	100	51460	100	57718	100

Source: Revenue Dept., Peeplu and Tonk Tehsil, 1987-89 to 2017-19

From 1987-89 to 2017-19, there has been a noticeable shift in the spatial variation of major crops in the study region. Bajra is a traditional staple food crop, showed a decline from 5448 hectares in 1987-89 to 3765 hectares in 2017-19. Barley also showing a decreasing trend in cultivation, with barley dropping from 3324 hectares to 448 hectares during the same period. Groundnut and gram cultivation exhibited a declining trend from 1987-89 to 2017-19 in the study region due to the change in rainfall pattern. Fodder crops (Jowar and Maize) account for a small proportion of the total cultivated area in the study area. Jowar crop area is fluctuating but generally remained stable over the years, reaching 6104 hectares in 2017-19. Maize, another significant crop which is declining from 12196 hectares in 1987-89 to 356 hectares in 2017-19. Chilly crop is also showing the decreasing trend from 1987-89 to 2017-19 due to change in climatic condition and plant virus effect. Moong cultivation exhibited a fluctuating trend from 1987-89 to 2017-19. In 1987-89, moong occupied merely 7740 hectares of the cultivated land. From 1997-99 to 2007-09, moong cultivation shown increasing trend from 2784 hectares to 3945 hectares. But in 2017-19, moong shows the decreasing trend due to the heavy rainfall. At the village level, mustard cultivation exhibited an increasing trend from 1987-89 to 2017-19. In 1987-89, mustard occupied merely 6105 hectares of the cultivated land. Between 1997-99 and 2007-09, there was an increasing from 18144 hectares in 1997-99 to 22478 hectares in 2007-09. However, from 2017-19 onwards, mustard cultivation experienced a continue positive trend at the command area. Turmeric and Sesame crops exhibited a fluctuating trend from 1987-89 to 2017-19. Urad cultivation exhibited an increasing trend from 1987-89 to 2017-19 due to market demand and rainfall. Kharif vegetables is also exhibited a fluctuating trend from 1987-89 to 2017-19. On the other hand, wheat experienced a decline from 11196 hectares in 1987-89 to 4052 hectares in 2017-19, reflecting changes in agricultural practices and market demands.

The timeframe spanning from 1987-89 to 2017-19 marked notable shifts in the distribution and proportions of key crops in the examined region. Certain crops, including Bajra, Groundnut, Maize, and Chilly, either saw a decline or maintained a consistent trend. In contrast, others such as Mustard, Wheat, Urad, and Moong exhibited substantial growth. These changes underscore the dynamic nature of agricultural practices influenced by factors like the adoption of hybrid seeds, increased use of fertilizers, improved irrigation facilities, modern farming technologies, climate variations (including rainfall and temperature fluctuations), concerns related to land degradation, evolving market demands, and broader economic factors throughout this time period.

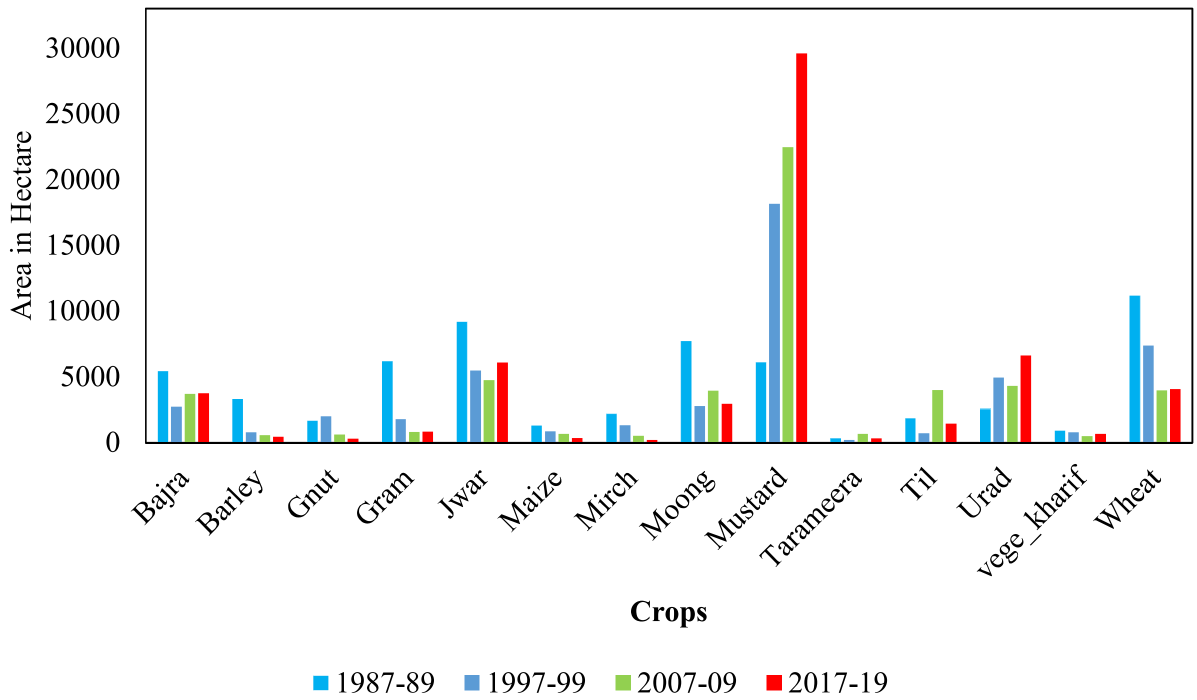
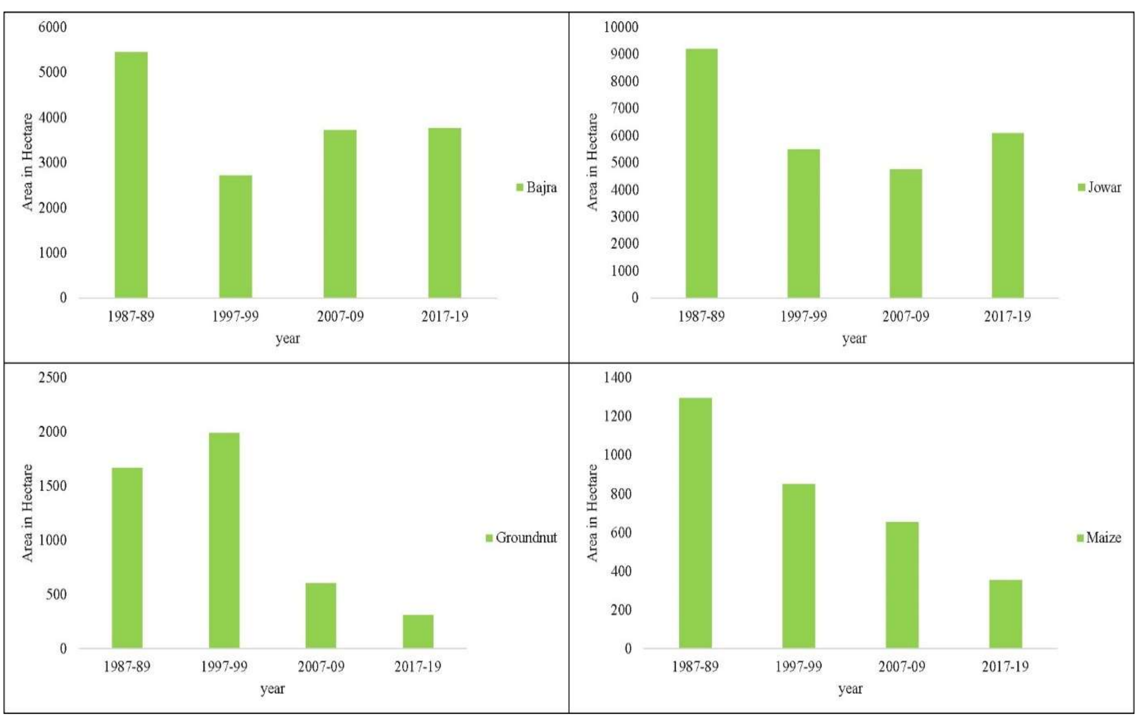
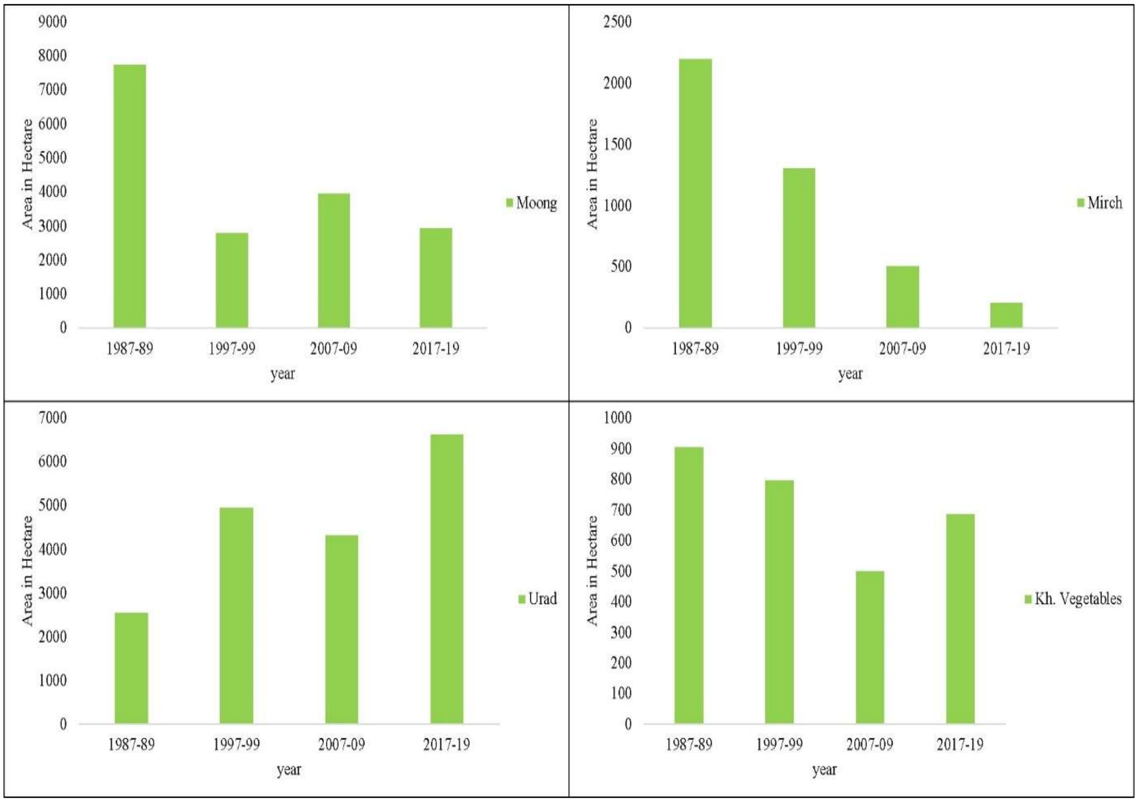


Fig. 1 Area under major crops at the Mashi Dam Command Area (1987-89 to 2017-19)




Area in Hectare
year
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1997-99
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Moong
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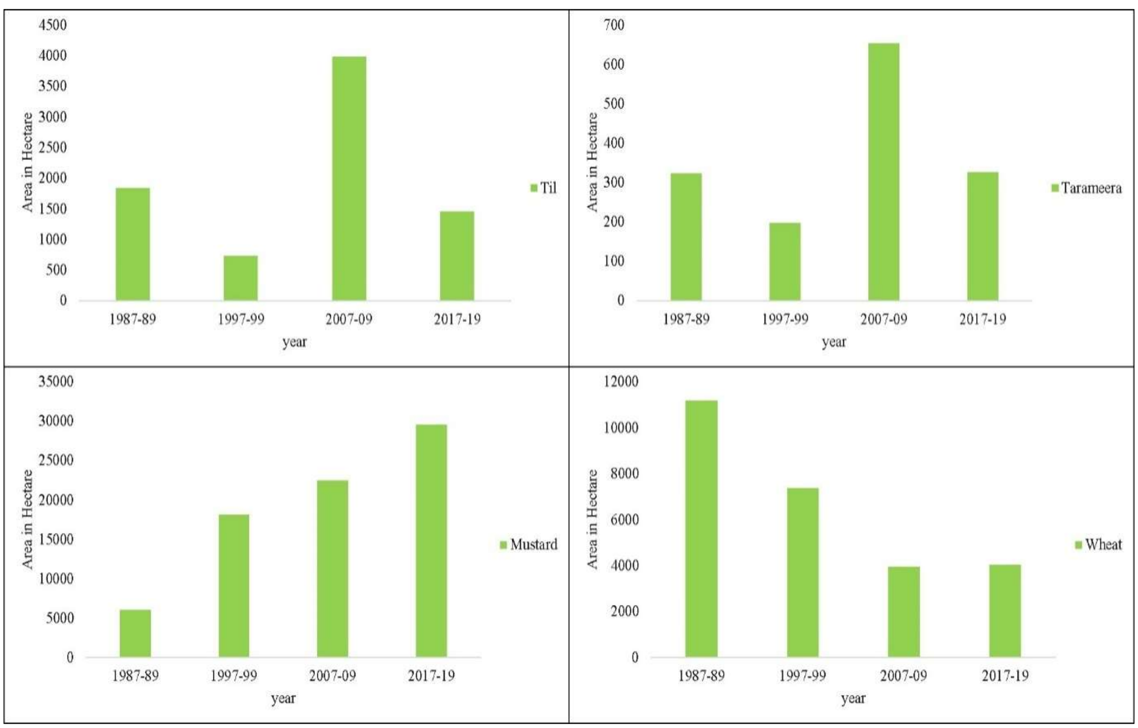
Kh. Vegetables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Mustard
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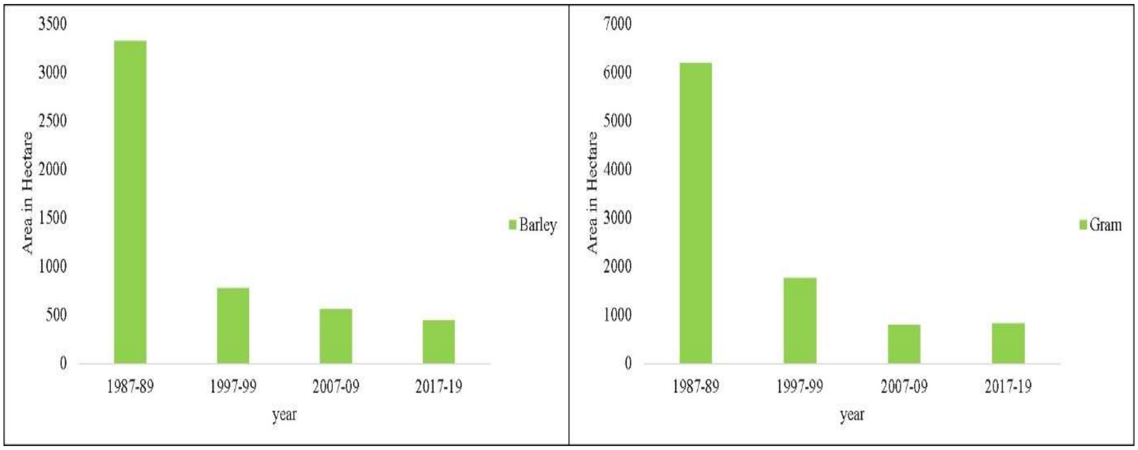
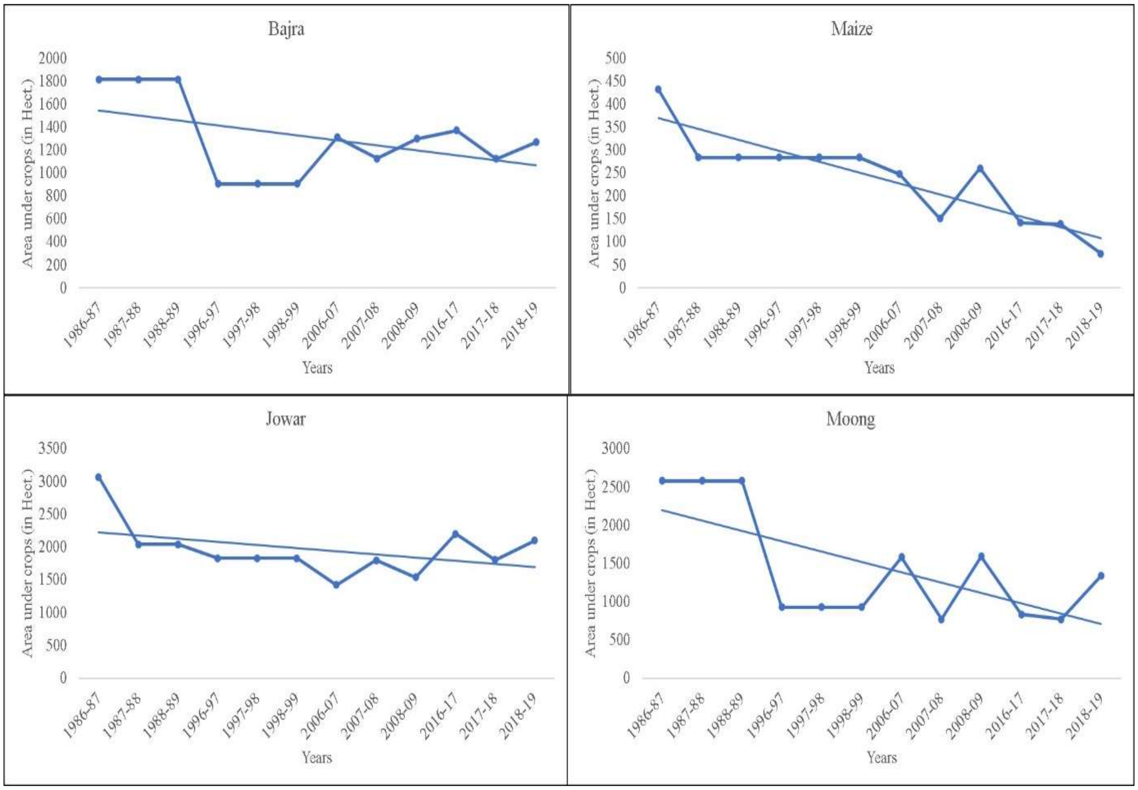


Fig. 2 Area under Major crops at the Mashi command area from 1987-89 to 2017-19

3.2 Trend analysis of individual crop

It is important to comprehend the state of each crop as they tend to fluctuate in their gross cropped area. Hence, this part focuses on examining the trends of major crops during the time period of 1987–89 to 2017-19. The trend analysis was conducted on the 14 major crops using a trend line based on their gross cropped area. The trend line shows the direction of the crop trend, whereas the actual line reflects the actual gross cropped area in the corresponding year. The trend analysis shows that out of the 14 crops, 02 crops have rapidly rising trends, 03 crops are stable, while 09 crops have a rapid decreasing trend. All trend line graphs are depicted in Figures 3 and 4.

The trend line graph offers a wide-ranging perception into the intricate patterns of gross cropped area in the study region spanning from 198-879 to 2017-19. Several significant conclusions emerge from the data: Bajra cultivation remained relatively steady, showing minor fluctuations, while maize experienced a consistent decline, indicating a decrease in production. Jowar cultivation, marked by fluctuations, saw a substantial increase in production during 2016-17 and 2017-18. Pulses like moong, urad, and gram displayed varying trends, exhibiting fluctuations in production levels. Among oilseeds, Sesame cultivation remained stable, groundnut production showed minor fluctuations, and mustard exhibited a remarkable upward trajectory, peaking in 2018-19. Taramira also displayed a noticeable increase in cultivation during the later years. Vegetables, particularly Kh. vegetables, remained stable, whereas Chilly cultivation showed fluctuations, including a sharp decrease in 2016-17. Cereal crops like wheat and barley experienced fluctuations, with both showing decreasing trends, particularly barley, which hit its lowest point in 2018-19. These diverse trends highlight the dynamic nature of agricultural practices influenced by factors such as market demand, climate conditions, and agricultural policies. These fluctuations underscore the ever-changing landscape of crop cultivation in the region, reflecting the adaptability of farmers to external influences over the specified years.



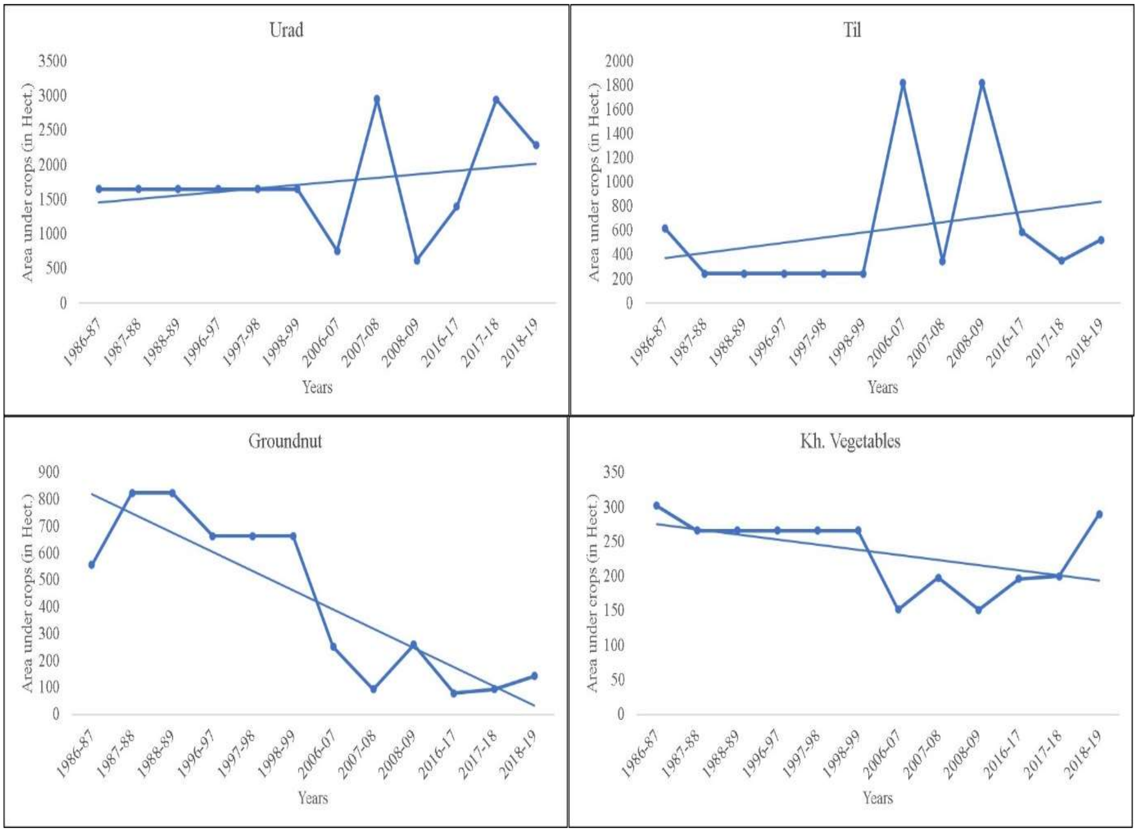
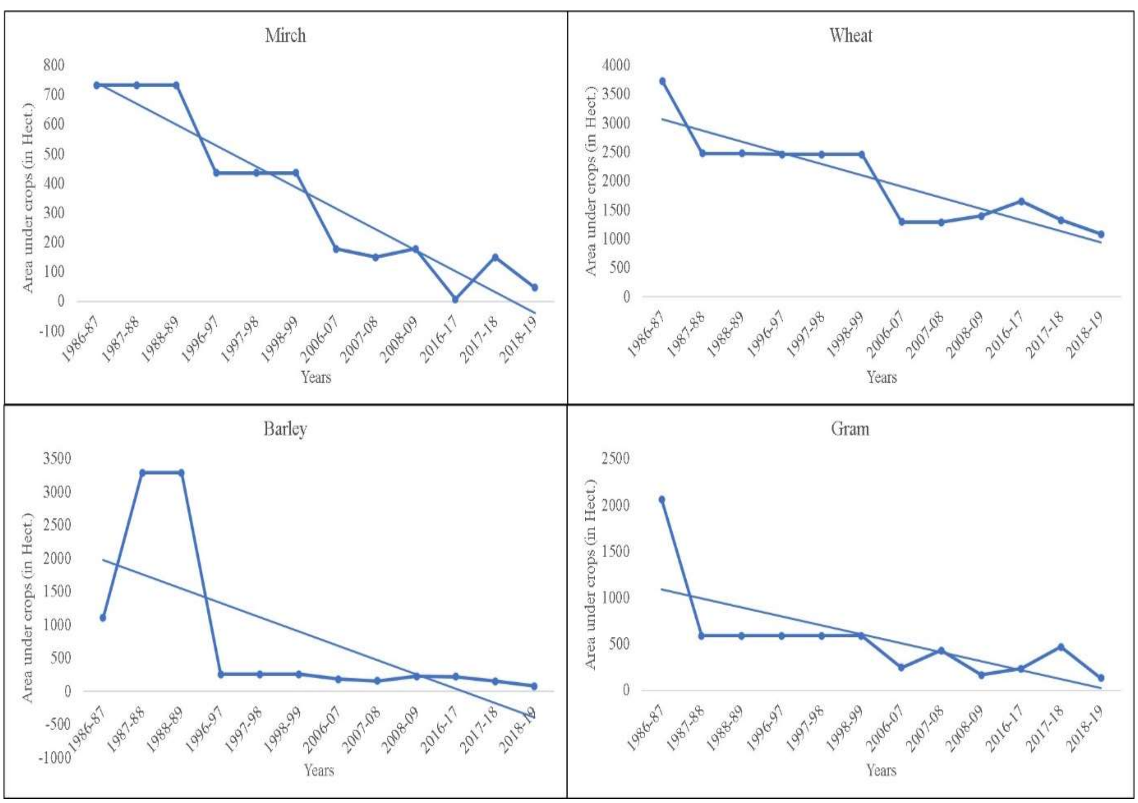


Fig. 3 Trend analysis of kharif crops (1987-2019)



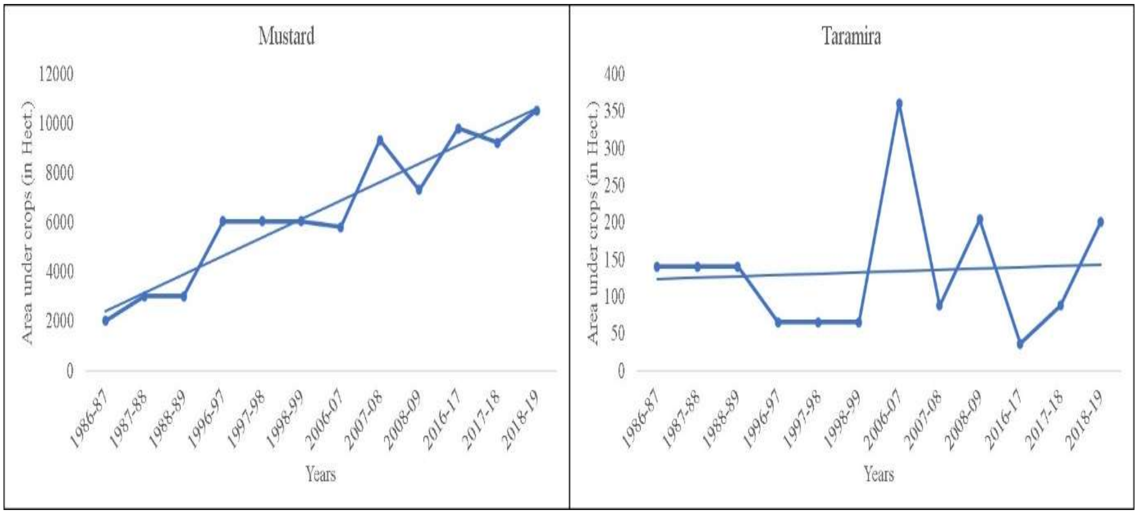


Fig. 4 Trend analysis of rabi crops (1987-2019)

3.3 Cropping intensity

Cropping intensity is a measure of the intensity of agricultural land use, and is defined as the ratio of gross cropped area to the net sown area. In this measurement, cropping intensity was calculated for each village from 1987-89 to 2017-19 using the secondary datasets. The cropping intensity provide the level of agricultural activity in each village and the extent to which land is being utilized for crop cultivation. The measurement of cropping intensity was classified in to five categories based on the percentage, such as Very Low (31.33-97.70), Low (97.71-164.08), Moderate (164.09-230.45), High (230.46-296.83), and Very High (296.84-363.21). Table 3 is depicted the results of the cropping intensity of 38 villages at the Mashi command area.

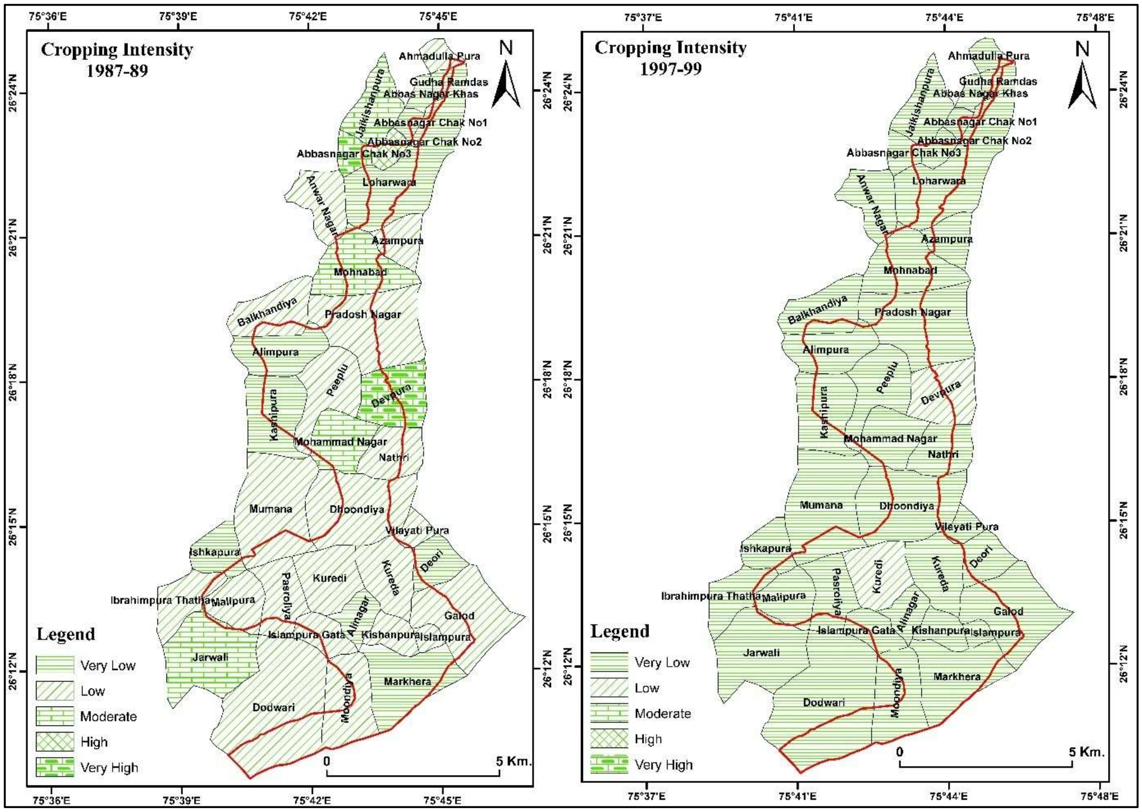
Table 3 Cropping Intensity in Mashi CMD Area (1987-89 to 2017-19)

Sl. No.	Classes	No. of villages (38)				
		Range in %	1987-89	1997-99	2007-09	2017-19
1	Very Low	31.33-97.70	10	36	2	1
2	Low	97.71-164.08	21	2	33	21
3	Moderate	164.09-230.45	4	Nil	3	13
4	High	230.46-296.83	1	Nil	Nil	3
5	Very High	296.84-363.21	2	Nil	Nil	Nil

Source: Computed by the researcher

Figure 5 presents the spatial-temporal analysis of cropping intensity at the Mashi CMD Area from 1987-89 to 2017-19 reveals fascinating patterns as well as changing trends in agricultural land use and efficiency. In the category of "Very Low" cropping intensity (31.33-97.70%), there is a clear temporal evolution. During the time periods 1987-89, 10 villages had into this class, which were lied in northern-western part of the study area, but by 1997-99, the number significantly increased to 36 villages, which were lied in all direction of the study area, indicating a shift towards more intense cropping. However, during the subsequent years (2007-09 and 2017-19), only 02 villages, namely Abbas Nagar Khas and Anwar Nagar were found in 2007-09 and one village, Alinagar, was also found in 2017-19 in this category. These villages were lied in the northern-western part and southern portion of the study region, indicating a decline in the prevalence of very low cropping intensity. The "Low" cropping intensity category (97.71-164.08%) displays dynamic trends. In 1987-89, 21 villages had into this class, which were lied in the southern part of the study area, decreasing to 2 in 1997-99. However, there was a subsequent increase from 2 to 33 villages in 2007-09, followed by a slight decrease from 33 to 21 villages in 2017-19, highlighting variability in cropping intensity within the low range over the years. Villages characterized by "Moderate" cropping intensity (164.09-230.45%) shows fluctuations. In 1987-89, 04 villages (Jaikishanpura, Mohnabad, Mohammad Nagar and Janwali) had into this class, which were lied in west and north part of the study area, while none were classified as having moderate cropping intensity in 1997-99. The number increased from 0 to 03 in 2007-09 and further 03 to 13 in 2017-19, indicating a resurgence of moderate cropping intensity category from 2007-09 to 2017-19. The "High" cropping intensity class (230.46-296.83%) showed limited pattern, with only one village (AbbasnagarChak 2), had into this class in 1987-89, which was lied in the northern part of the study area. In 2017-19, 03 villages had in this class, namely Devpura, Nathri, and Abbasnagar Chak 2, which were lied in the eastern and northern parts of the study area. However, there was no village in this class during the periods of 1997-99 and 2007-09, indicating variability and a low prevalence of high cropping intensity. In the time period 1987-89, within the "Very High" cropping intensity class (296.84-363.21%), 02 villages, had in to this class, namely Devpura and Abbasnagar Chak 3. These villages were situated in the east and north directions of the study area. However, in the subsequent years (1997-99, 2007-09, and 2017-19), there were no villages in this class, indicating a significant decline in cropping intensity in the very high category.

The results of the cropping intensity show the complex and evolving nature of cropping intensity at the Mashi CMD Area. The observed patterns suggest shifts in agricultural practices and land use dynamics over the specified time periods, emphasizing the need for ongoing monitoring and adaptive strategies to ensure sustainable and efficient land use in the study area. Geo-spatial analysis of cropping intensity shows the evolution of agricultural strategies and land utilization from 1987-89 to 2017-19. The outcomes of this study will aid policymakers in identifying areas with the potential for boosting agricultural productivity and enhancing land use efficiency.



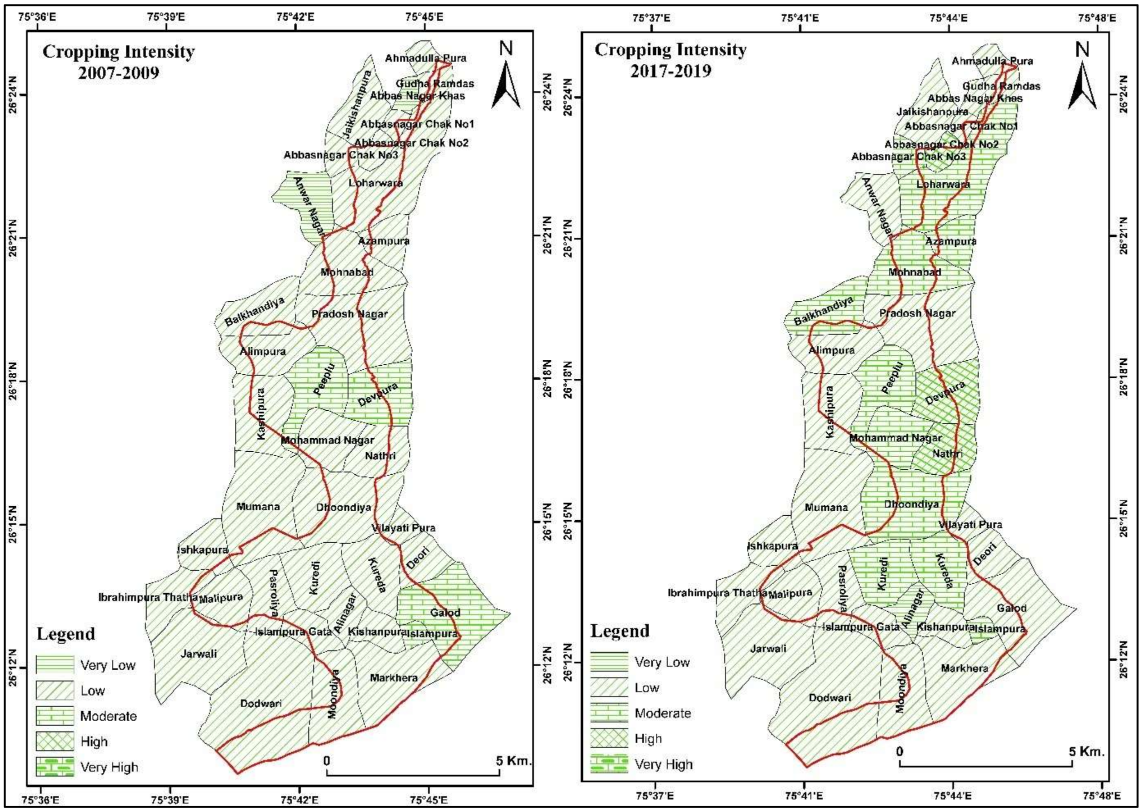


Fig. 5 Cropping intensity in Mashi CMD Area (1987-89 to 2017-19)

3.4 Crop diversification

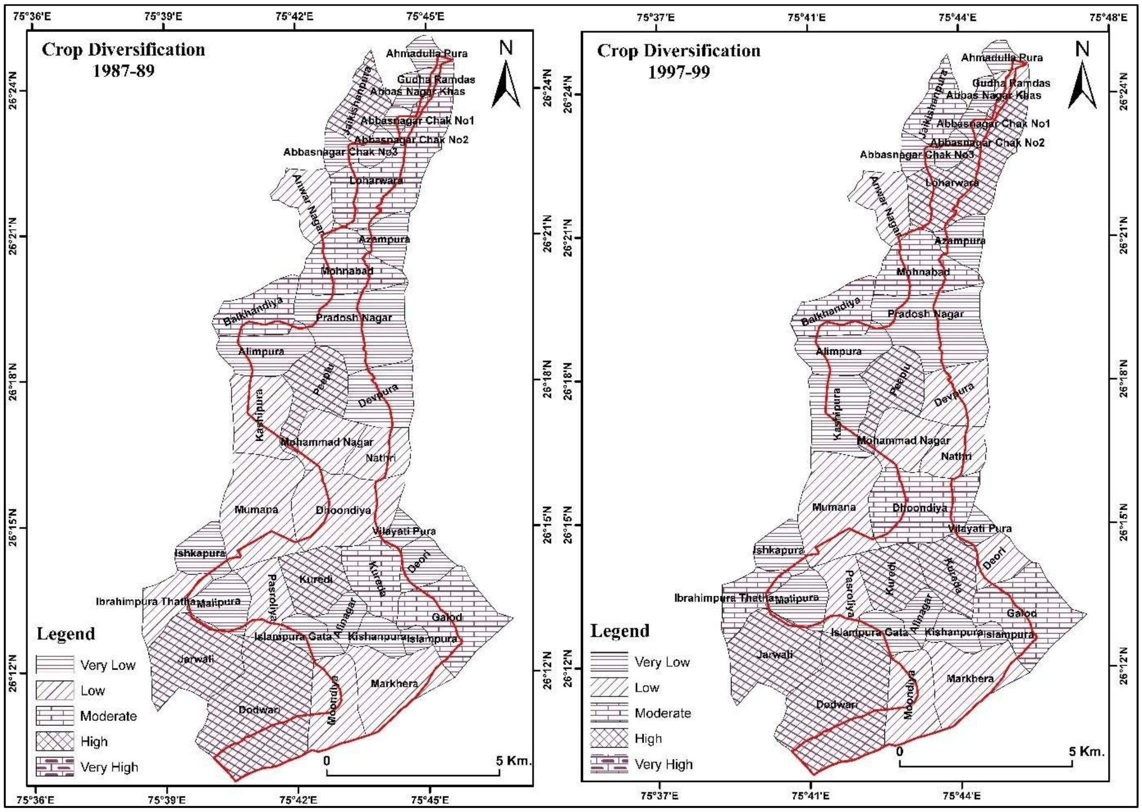
Crop diversification refers to the practice of growing different types of crops instead of specializing in one crop. It is important to understand the level of diversification in a region in order to analyse its cropping patterns. Crop diversification is now a common practice in most regions of the world where agriculture is stable. Farmers in developing countries typically grow a variety of crops in their fields throughout the agricultural year. The degree of crop diversification depends on several factors such as the geographical and climatic conditions of the area, the socioeconomic status of the farmers, and the level of technological development in the region. Modern irrigation techniques, fertilizer use, high-yielding seed varieties, and mechanization have made crop diversification possible (Bhatia, 1965). Other factors that influence crop diversification include the weather, rural life and self-subsistence farming practices, and the demand for different crops in the market. Observations at the village level show that farmers in all villages at CMD area grow several crops in their fields during the 1987-89 to 2017-19.

Table 4 Crop diversification in Mashi CMD Area (1987-89 to 2017-19)

Sl. No.	Classes	No. of villages (38)				
		Range in %	**1987-89**	**1997-99**	**2007-09**	**2017-19**
1	Very Low	0.40-14.68	18	16	16	20
2	Low	14.69-28.96	10	10	12	12
3	Moderate	28.97-43.25	5	6	7	6
4	High	43.26-57.53	5	6	2	Nil
5	Very High	57.54-71.82	Nil	Nil	1	Nil

Source: Computed by the Researcher.

Table 4 and Figure 6 presents the spatial-temporal analysis of crop diversification at the Mashi CMD Area spanning from 1987-89 to 2017-19 provides vital information about the changing agricultural diversification at the study site. The study categorizes crop diversification into five classes based on percentage ranges, ranging from "Very Low" to "Very High." The observed trends reveal dynamic patterns in the diversification of crops across the study area villages. In the category of "Very Low" crop diversification (0.40-14.68%), there is a noticeable temporal shift. In 1987-89, eighteen villages had into this class, which were lied central and north part of the study area, decreasing from 18 villages to 16 villages in further 1997-99 and 2007-09. However, there was a subsequent increase to 20 villages in 2017-19, which were situated in the north and eastern part of the study area, indicating a fluctuating but overall increasing trend in crop diversification within the very low range. The "Low" crop diversification class (14.69-28.96%) exhibits low variability in the study region. In 1987-89, 10 villages were classified in this class, which were lied in the eastern and southern portion of the study area, remaining same consistent in 1997-99, and then increasing from 10 to 12 in 2007-09. However, there was a subsequent increase from 10 to 12 villages between 2007-09 and 2017-19, reflecting increasing trend in crop diversification within the low range. Villages characterized by "Moderate" crop diversification (28.97-43.25%) display fluctuations and stability in diversification pattern. In 1987-89, five villages had into this class, increasing to 06 in 1997-99, and then increasing to 07 in 2007-09. The observed increasing trend was identified from the northern to western sectors of the study area. there was a subsequent decrease from 07 villages to 06 villages in 2017-19, suggesting changing and stable patterns of crop diversification within the moderate class over the years. The "High" crop diversification class (43.26-57.53%) exhibits a declining trend. In 1987-89, five villages were classified in this class, increasing to 06 in 1997-99, but decreasing from 06 to 02 in 2007-09. Notably, there was no representation in this class in 2017-19, indicating a decreasing tendency in villages. The observed decreasing trend was found western regions of the study area. In the "Very High" crop diversification class (57.54-71.82%), there is a notable absence of pattern in 1987-89, 1997-99, and 2017-19. However, there is a single village into this class in 2007-09, which was lied in the central part of the study area, indicating a short-term but limited occurrence of very high crop diversification during this period.



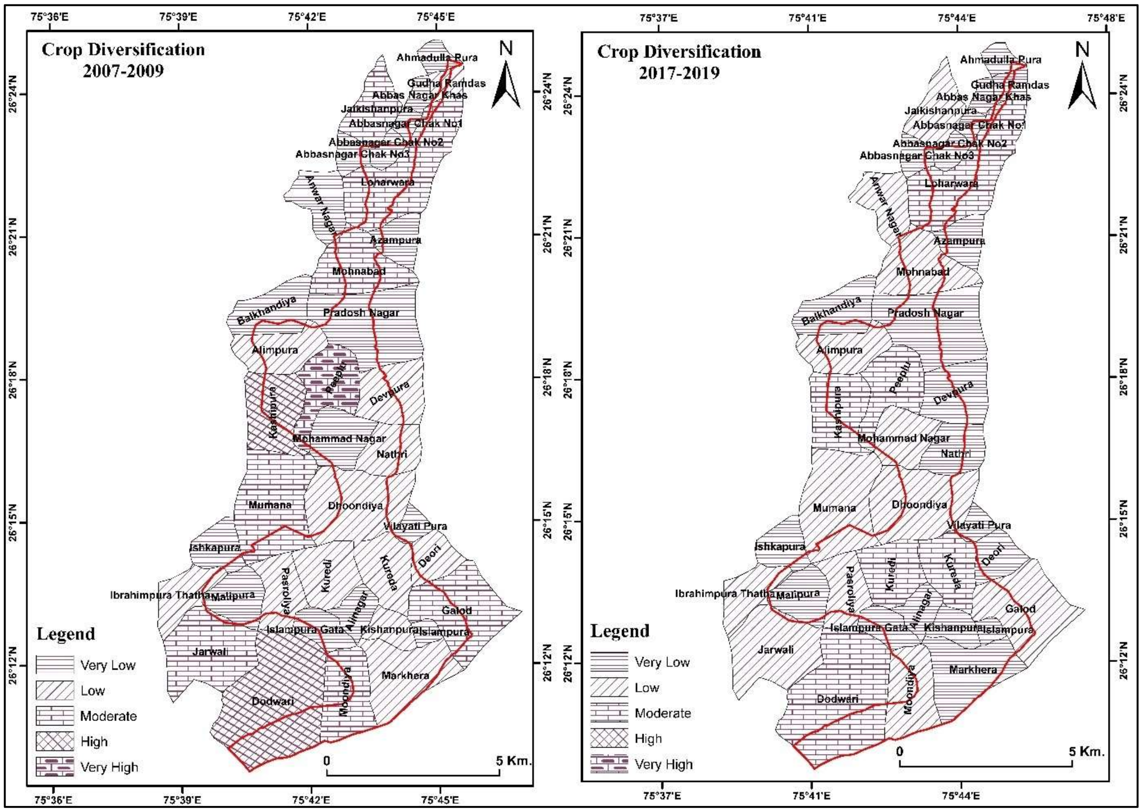


Fig. 6 Crop diversification in Mashi CMD Area (1987-89 to 2017-19)

The results of the crop diversification show the evolving nature at the Mashi CMD Area. The observed patterns reflect dynamic shifts in agricultural practices and highlight the need for ongoing monitoring to understand the factors influencing crop diversification trends over the specified time periods.

3.5 Crop yield index

Crop yield index refers to the average yields of different crops on a farm or in a specific locality in comparison to the yields of the same crops on another farm or in a different locality. To estimate crop yield index, Yang's (1965) method was used for the year from 1987-89 to 2017-19. The crop yield index was calculated by comparing the yield of selected crops in the CMD villages with the average yield of those crops in the Peeplu region. This index is calculated as a percentage by dividing the yield kg/hectare of crops on a specific farm (village) by the average yield of the same crop in the entire region (Peeplu). The resulting percentage is then multiplied by 100 to obtain the index number. Each crop's area is considered as a weight, and by multiplying this with the percentage index, products are obtained. Summing up these products and dividing the total by the CMD cropped area yields the average index, serving as the desired crop index for the district, with crop area serving as the weight in the calculation. Village crop yield index calculation is shown in Table 5.

Table: 5 Crop Yield Index Calculation

Crops	Village Avg. Yield Kg/Hect.	Peeplu Avg. Yield Kg/Hect.	Village Cropped Area	Crop Yield on Village As % of Peeplu Yields	% Multiplied By Hect.
Maize	850	900	20	94.44	1888.89
Jowar	1715	995	432	172.36	74460.30
Bajra	1535	1668	246	92.03	22638.49
Urad	294	326	131	90.18	11814.11
Moong	296	455	65	65.05	4228.57
Sesame	289	364	97	79.40	7701.37
Groundnut	1162	1285	3	90.43	271.28
Wheat	3899	3565	230	109.37	25154.84
Barley	2151	2547	32	84.45	2702.47
Gram	1248	1457	10	85.66	856.55
Mustard	1700	1702	1566	99.88	156415.98
Taramira	675	870	1	77.59	77.59
Total	15814	16134	2833	1140.84	308210.45
		CYI	108.79		

Table 6 Crop Yield Index in Mashi CMD Area (1987-89 to 2017-19)

Sl. No.	Classes	No. of villages (38)				
		Range in %	1987-89	1997-99	2007-09	2017-19
1	Very Low	58.15-71.08	6	4	18	15
2	Low	71.09-84.00	11	12	6	9
3	Moderate	84.01-96.93	5	2	12	12
4	High	96.94-109.86	12	18	2	2
5	Very High	109.87-122.79	4	2	Nil	Nil

Source: Computed by the researcher

Table 6 and Figure 7 presents the geo-spatial pattern of crop yield index at the Mashi CMD villages from 1987-89 to 2017-19. This index further classified into five classes based on the range of yield index and the number of villages within each category. In the "Very Low" crop yield index category (58.15 to 71.08%), there is a noticeable temporal trend observed in the study villages. In 1987-89, six villages fell into this category, situated in the western parts of the study area. This number decreased from 06 villages to 04 villages in the subsequent period of 1987-89. However, there was a notable increase from 1997-99 to 2007-09, with the number rising from 04 to 18 villages during that period. These villages were located in the central and southern parts of the study area, indicating a fluctuating but overall increasing trend in the crop yield index within the very low class. The number decreased slightly from 18 to 15 during 2007-09 to 2017-19, suggesting a temporal shift in this class from 2007-09 to 2017-19. The "Low" crop yield index category (71.09-84.00%) demonstrates stable and decreasing trends over time. In 1987-89, eleven villages fell into this category, situated in the western part of the study area. There was minimal change, with the number increasing slightly from 11 to 12 in 1997-99. However, in the between period from 1997-99 to 2007-09, a clear decreasing trend was observed, with the number of villages decreasing from 12 to 06. This pattern was observed from western to eastern part of the villages in the study area due to the soil degradation issues. This period showed a drastic decline in the crop yield index within the low range. Conversely, from 2007-09 to 2017-19, there was an increase from six villages to nine villages across the study area. In the "Moderate" category (84.01 and 96.93), there were 05 villages in 1987-89, two villages in 1997-99, twelve villages in 2007-09, and twelve villages in 2017-19. This class exhibits a clear increasing trend in crop yield index at the command villages from 1987-89 to 2017-19. The observed pattern indicates a shift from north-centre villages to south-east villages due to land degradation and soil quality depletion issues. In the "High" class (96.94 to 109.86) had 12 villages in 1987-89, 18 in 1997-99, 2 in 2007-09, and 2 in 2017-19. This class is showing the decreasing pattern in the eastern and western villages at the Mashi command villages. In the "Very High" category (yield index ranging from 109.87 to 122.79) had 4 villages in 1987-89 and 2 in 1997-99, with none recorded in subsequent years. This class is also showing the decreasing trend in southern portion of the study area from 1987-89 to 2017-19.

The data reveals fluctuations in the crop yield index across different intensity classes over the years. The results highlight the dynamic nature of crop productivity in the Mashi CMD Area. While some villages experienced improvements in crop yield indices, others faced challenges or inconsistencies. Further analysis is necessary to identify the factors influencing these variations, such as agricultural practices, soil quality, water availability, and climate conditions. Understanding these factors is important for implementing targeted interventions to enhance crop productivity, ensuring sustainable agricultural practices in the region. Continuous monitoring and research are essential to support evidence-based decision-making for the agricultural sector.

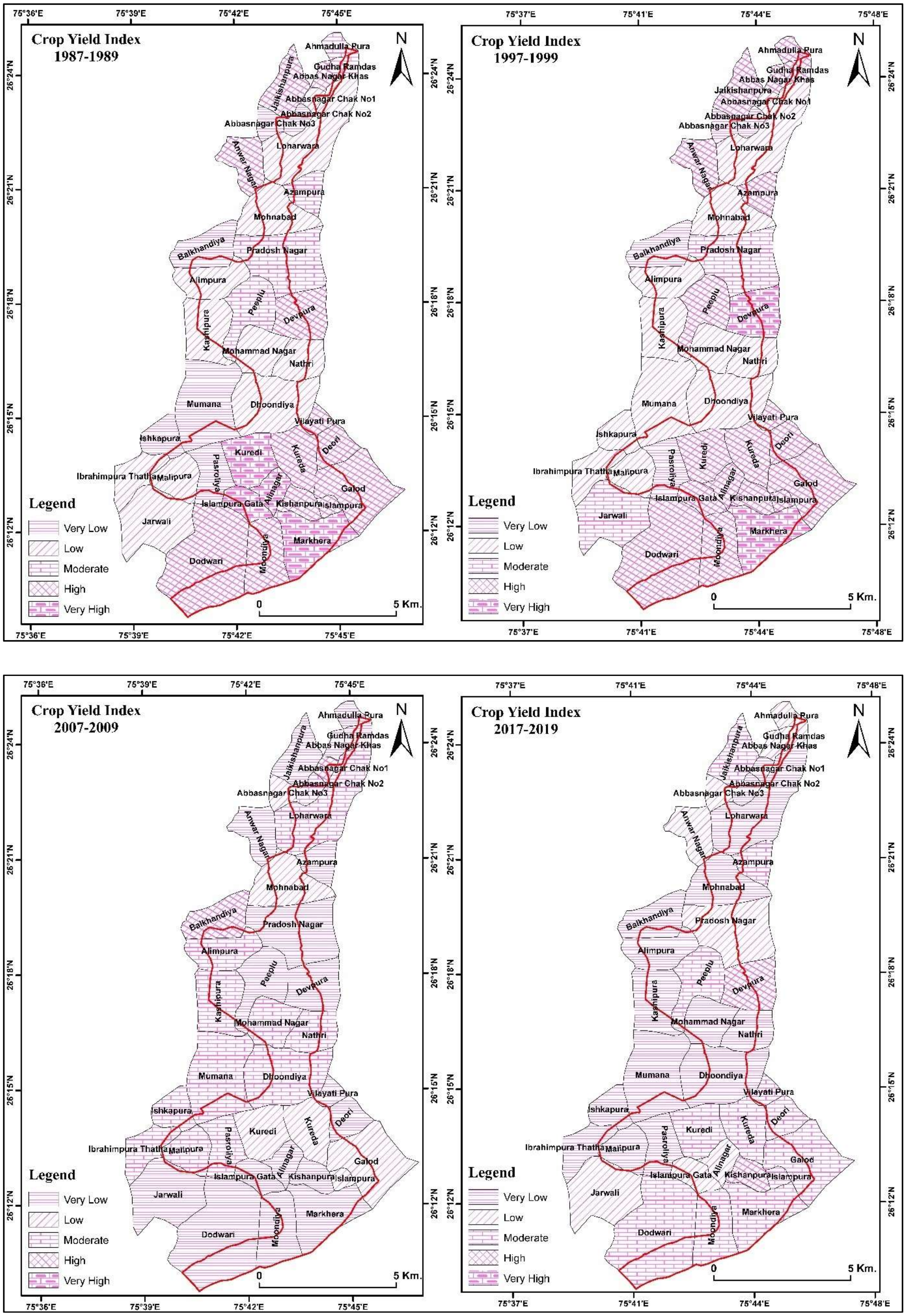


Fig. 7 Crop yield index in Mashi CMD Area (1987-89 to 2017-19)

4 Conclusion

The comprehensive analysis of distinct agricultural statistics (in terms of cropping pattern) in the Mashi Command Area from 1987-89 to 2017-19 provides valuable information into the dynamic nature of cropping patterns and agricultural practices. The examination of crop concentration indicates a notable shift in the distribution of major crops. While some crops, such as Mustard, Wheat and Urad, experienced an increase and stable in concentration, others like Bajra and Groundnut showed a decrease pattern. This signifies a changing landscape in crop preferences and cultivation strategies. Cropping intensity, an important measure of agricultural land use or efficiency, demonstrated fluctuations over the years. Factors such as climate change, soil and land degradation, technological advancements, and socio-economic conditions likely contributed to these variations. The observed changes in crop combinations from three to ten crops highlight the adaptability of farmers to evolving agricultural trends. Crop diversification, as evidenced by the cultivation of a wider variety of crops, reflects efforts to mitigate risks and enhance overall agricultural sustainability. Furthermore, the Crop Yield Index provides important information about the productivity of various crops. The reasons behind the observed changes in crop yield were multifaceted, including factors such as waterlogging, land degradation, salinity, climate change, and human induced activities. The intricate interplay of these factors shapes the agricultural landscape in the Mashi command area. In conclusion, the trends observed in crop concentration, cropping intensity, crop combinations, crop diversification, and crop yield index underscore the complex and dynamic nature of agriculture in the Mashi Command Area. Multiple factors (climate, soil fertility, land degradation, market demand, government policies, and farmer preferences) have influenced agricultural practices as well as cropping patterns, and understanding these factors is important for informed policy-making and sustainable agricultural development in the study region.

References

Pande, N., & Deshmukh, P. (2015). ICT: A path towards rural empowerment through telecommunication, e-governance, and e-agriculture. IBMRD's Journal of Management & Research, 4(2), 47-54.

Mondal, S., Jeganathan, C., Sinha, N. K., Rajan, H., Roy, T., & Kumar, P. (2014). Extracting seasonal cropping patterns using multi-temporal vegetation indices from IRS LISS-III data in Muzaffarpur District of Bihar, India. The Egyptian Journal of Remote Sensing and Space Science, 17(2), 123-134.

Khan, M., & Ahmad, A. (2019). Changing Cropping Pattern in Kheri District, Uttar Pradesh, India. Economic Affairs, 64(4), 803-812.

Feder, G., & Umali, D. L. (1993). The adoption of agricultural innovations: a review. Technological forecasting and social change, 43(3-4), 215-239.

Sridharan, B., & Radhakrishnan, A. (1978). A Study on the Factors Affecting Changes in the Cropping Pattern in Nilgiris District, Tamil Nadu. Indian Journal of Agricultural Economics, 33(902-2018-1480), 14-21.

Akhtar, R., & Acharya, R. (2015). Changes in cropping pattern in Jammu and Kashmir. International Journal of Advanced Research in Education & Technology (IJARET), 2(4).

Bhatia, S.S., (1965). "Patterns of Crop Concentration and Diversification in India", Economic Geography, 41. pp. 40-56.

District Statistical Handbook (1987-89, 1997-99, 2007-09, 2017-19). Tonk District, Directorate of Economics and Statistics, Govt. of Rajasthan.