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CHANGES IN AGRICULTURAL LAND-USE PATTERNS AND THEIR EFFECTS ON CROPPING AND IRRIGATION INTENSITY IN VARANASI DISTRICT, U.P., INDIA.

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ABSTRACT

Land use and cropping patterns are vital components of agricultural geography, reflecting how land resources are managed. In Varanasi district, rapid population growth and urbanisation have reduced cultivable land, prompting shifts in agricultural land use. This study analyses secondary data from 2011–12 and 2020–21 to assess changes in net sown area, gross cropped area, and irrigated land. Findings show a gradual decline in agricultural land due to urban expansion and non-farm activities, while both cropping intensity and irrigation intensity increased, indicating intensification on the remaining land. Pearson correlation results reveal that the relationship between cropping and irrigation intensity strengthened from a moderate positive level in 2011–12 to a strong, statistically significant level in 2021–22. However, Fisher's r-to-z test confirms that the rise in correlation is not statistically significant. The study underscores the importance of sustainable land and water management to support agricultural productivity amid shrinking land resources.

KEY WORDS: *Cropping Intensity, Irrigation Intensity, Land Use, Net Sown Area, Gross Cropped Area*

1. INTRODUCTION

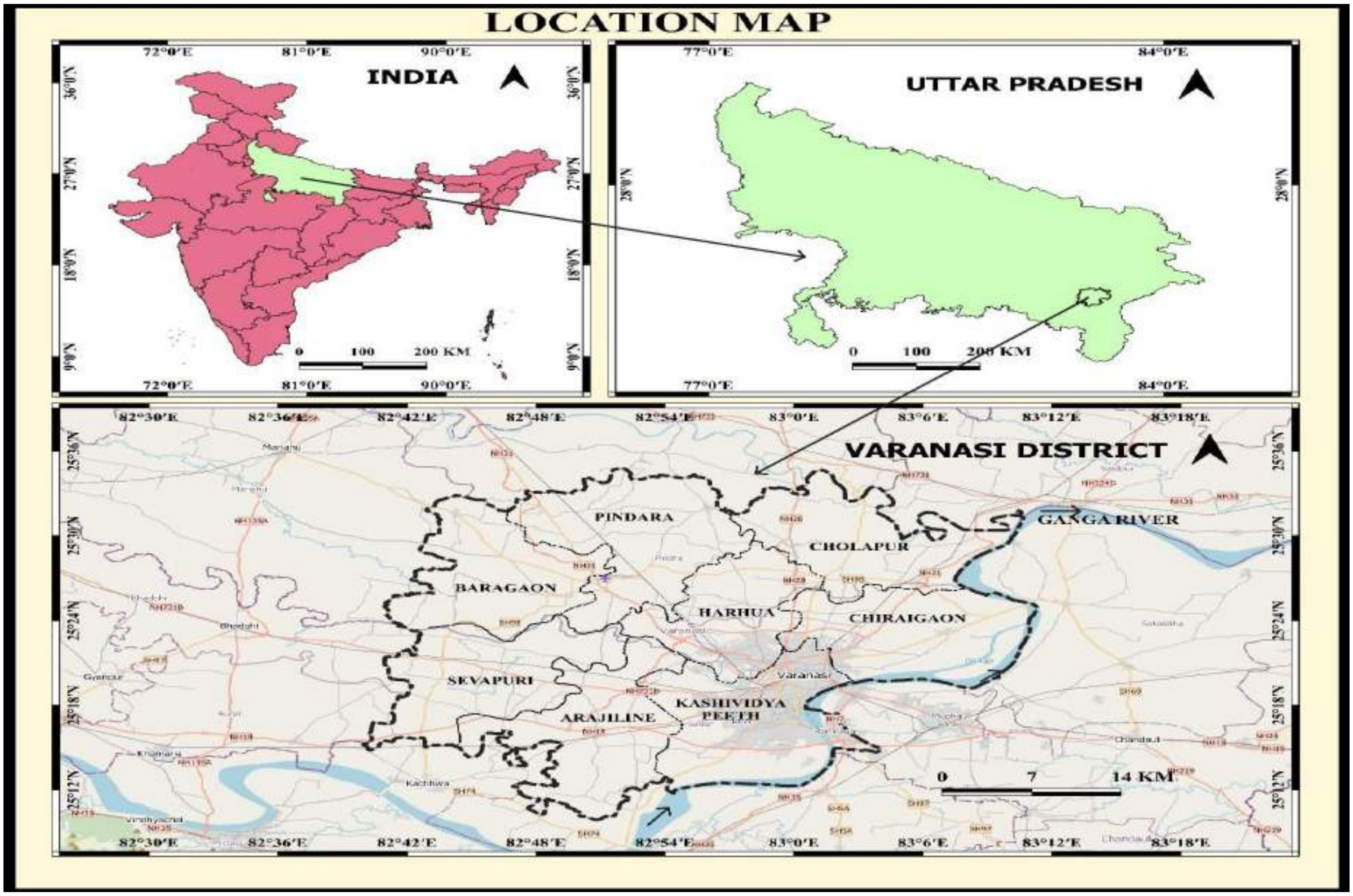
Agriculture is the backbone of India's rural economy, providing livelihoods to a large section of the population and shaping the socio-economic fabric of the country. As a finite and non-renewable resource, land forms the basis of agricultural activity. Yet, rapid urbanisation, population growth, and changing socio-economic conditions have significantly transformed land-use patterns, especially in agriculturally dominant regions. Agricultural land-use dynamics reflect human interaction with land resources and indicate shifting societal priorities toward economic development and sustainability. Varanasi district, located in eastern Uttar Pradesh, exemplifies an area where agriculture remains the main occupation despite rising urban pressure and non-agricultural expansion. With fertile alluvial soils, a favourable climate, and a developed irrigation network, the district supports intensive cultivation of cereals, pulses, and cash crops. However, recent decades have seen marked changes in land-use structure, including reductions in net sown area, expansion of non-agricultural land, and declining fallow land. These shifts have significant implications for cropping intensity, irrigation intensity, agricultural productivity, and rural sustainability. As key indicators of agricultural development, cropping and irrigation intensity reflect land utilisation and water-use efficiency, both of which are influenced by changing land-use patterns, availability of cultivable land, access to irrigation, and modern farming practices.

2. LITERATURE REVIEW

The relationship between irrigation and cropping intensity has been widely studied in agricultural geography and development research. **Dayal (1978)** identified cropping intensity as a key indicator of agricultural land use, while **Dhawan (1988)** established a strong positive correlation between irrigation expansion and rising cropping intensity in India. **Dhawan and Datta (1992)** further confirmed that irrigation facilitates multiple cropping and stabilises productivity. Studies by **Bhattarai et al. (2002)** &**Hussain and Hanjra (2004)** revealed that irrigation enhances productivity, employment, and income, reducing rural poverty.Globally, **Siebert et al. (2010)** observed higher cropping intensity in irrigated regions. **Jain et al. (2013)** highlighted its importance for food security.At the regional level, **Hajare et al. (2014)** found that improved irrigation and infrastructure in Kolhapur promoted commercial cropping, and**Narayanamoorthy et.al. (2015)** noted that irrigation enables more intensive land use, essential for sustaining agricultural growth,while **Deshmukh and Shinde (2017)** documented a national rise in both irrigation and cropping intensity since 1950–51. In Nepal, **Kaini et al. (2020)** reported that commercialised irrigated farming boosts cropping intensity. **Mondal and Sarkar(2021)** observed that while irrigation generally increases cropping intensity, regional factors like soil quality and water management also significantly influence outcomes.

The above studies highlight irrigation as a key driver of cropping intensity; however, limited work exists on comparing temporal changes using Fisher's r-to-z, creating a gap addressed in the present study.

3. STUDY AREA



Varanasi district, situated in the southeastern part of Uttar Pradesh, lies between 25°10′ and 25°35′ N latitudes and 82°30′ and 83°10′ E longitudes.It covers an area of about 1,535 sq. km and comprises eight development blocks. The district is bounded by Mirzapur in the south, Chandauli in the east, Jaunpur in the north, and Sant Ravidas Nagar in the west. The region is part of the Middle Ganga Plain, with fertile alluvial soil and a subtropical monsoon climate,both of which support intensive agriculture. Major crops include rice, wheat, pulses, and vegetables, sustained by irrigation from canals, tube wells, and groundwater sources.

Figure 1: Location Map of the Study Area

4. OBJECTIVES

The specific objectives are:

- To analyse the spatial and temporal changes in agricultural land-use patterns in Varanasi district over the study period.
- To analyse the trends and variations in cropping intensity across various blocks of the district.
- To assess the tehsil–wise changes in irrigation intensity (2011-12 & 2021-22).
- To analyse the temporal relationship between cropping intensity and irrigation intensity.

5. HYPOTHESIS

- The temporal relationship between cropping intensity and irrigation intensity in Varanasi district has statistically strengthened over the period 2011–12 to 2021–22.

6. DATA SOURCES AND METHODOLOGY

The present study is primarily based on secondary data collected from various authentic governmentsources. The major sources of data include the District Statistical Handbook of Varanasi and the Directorate of Economics and Statistics (Government of Uttar Pradesh) for the years 2011–12 and 2021–22. Additional information has been obtained from the Department of Agriculture, statistical abstracts, to ensure consistency and reliability of the data.

METHODOLOGY

The analysis involves both quantitative and spatial techniques to assess the temporal and spatial variations in agricultural land-use patterns in the Varanasi district. The study period covers a decade (2011–12 to 2021–22), during which data were systematically compared to identify changes in land-use structure and agricultural intensity. Percentage and growth rate analyses were employed to determine the extent of change in different land-use categories. Cropping intensity and irrigation intensity were computed using standard formulas:

- $$\textbf{Cropping Intensity (\%)} = \frac{\textbf{Gross Cropped Area}}{\textbf{Net Sown Area}} \times \textbf{100}$$

- $$\textbf{Irrigation Intensity (\%)} = \frac{\textbf{Gross Irrigated Area}}{\textbf{Net Irrigated Area}} \times \textbf{100}$$

Further, comparative analysis was carried out to evaluate the interrelationship between cropping and irrigation intensity across the tehsils. Descriptive statistics were applied to interpret temporal trends,along with Pearson correlation to assess the relationship between cropping intensity and irrigation intensity. Fisher's r-to-z transformation was applied to statistically compare the strength of these correlations between 2011–12 and 2021–22 and determine whether the change over time was significant. To visualise spatial variations, thematic maps were prepared usingQ-GIS techniques, enabling a clear representation of land-use distribution and intensity patterns. The overall methodological approach integrates statistical computation with spatial interpretation to provide a comprehensive understanding of land-use transformation in the Varanasi district.

7. RESULT AND DISCUSSION

1. Spatial and Temporal Changes in Agricultural Land-Use Patterns

The agricultural land-use pattern between 2011–12 and 2021–22 shows significant spatial and temporal changes in Varanasi district. The total reporting area increased from 152,678 ha to 188,305 ha (23.33%), indicating an expansion of surveyed or cultivable land. Within this, however, notable shifts occurred across land-use categories. Forest area declined sharply by 66.67% (138 ha to 46 ha), reflecting deforestation and encroachment linked to agricultural expansion and urban development. Pasture land also decreased by 29.17%, signalling a reduced focus on livestock-based activities. In contrast, cultivable wasteland rose by 156.97%, and barren land increased drastically by 639.19%, pointing to land degradation, soil erosion, and declining productivity. Current fallow land decreased by 33%, showing re-cultivation of previously unused land, while other fallow land increased by 123.63%, indicating rising long-term fallows due to water scarcity, soil fertility issues, or labour shortages. Land under non-agricultural use grew by 31.73% (26,953 ha to 35,505 ha), highlighting rapid urbanisation and diversion of farmland. Although net sown area increased modestly by 11.66%, the area sown more than once declined by 8.17%, suggesting reduced cropping intensity due to limited irrigation or less intensive farming.Overall, the district experienced moderate growth in cultivated land but severe loss of forests and pastures, expansion of wasteland, and increasing conversion to non-agricultural uses. These trends reflect growing population pressure, urban expansion, and shifting economic priorities, underscoring the urgent need for sustainable land management and conservation to protect agricultural productivity.

Table 1: Agricultural Land-Use Patterns in Varanasi District (2011-12 & 2021-22)

Sl. No.	Agricultural Land-Use Pattern	2011-12		2021-22		Change
		Area (ha)	%	Area (ha)	%	%
1.	Total Reporting Area	152678	-	188305	-	**23.33**
2.	Forest Area	138	0.09	46	0.02	**- 66.67**
3.	Cultivable Wasteland	2933	1.92	7537	4.00	**156.97**
4.	Current Fallow	18387	12.04	12320	6.54	**-33.00**
5.	Other Fallow	4935	3.23	11036	5.86	**123.63**
6.	Barren and Uncultivable Land	1258	0.82	9299	4.94	**639.19**
7.	Land for use other than Agriculture	26953	17.65	35505	18.86	**31.73**
8.	Pastures	24	0.02	17	0.01	**-29.17**
9.	Net Sown Area	95698	62.68	106853	56.74	**11.66**

10.	Areas Sown More than Once	59444	38.93	54587	28.99	**- 8.17**

Sources:https://updes.up.nic.in/spideradmin/Hpage1.jsp

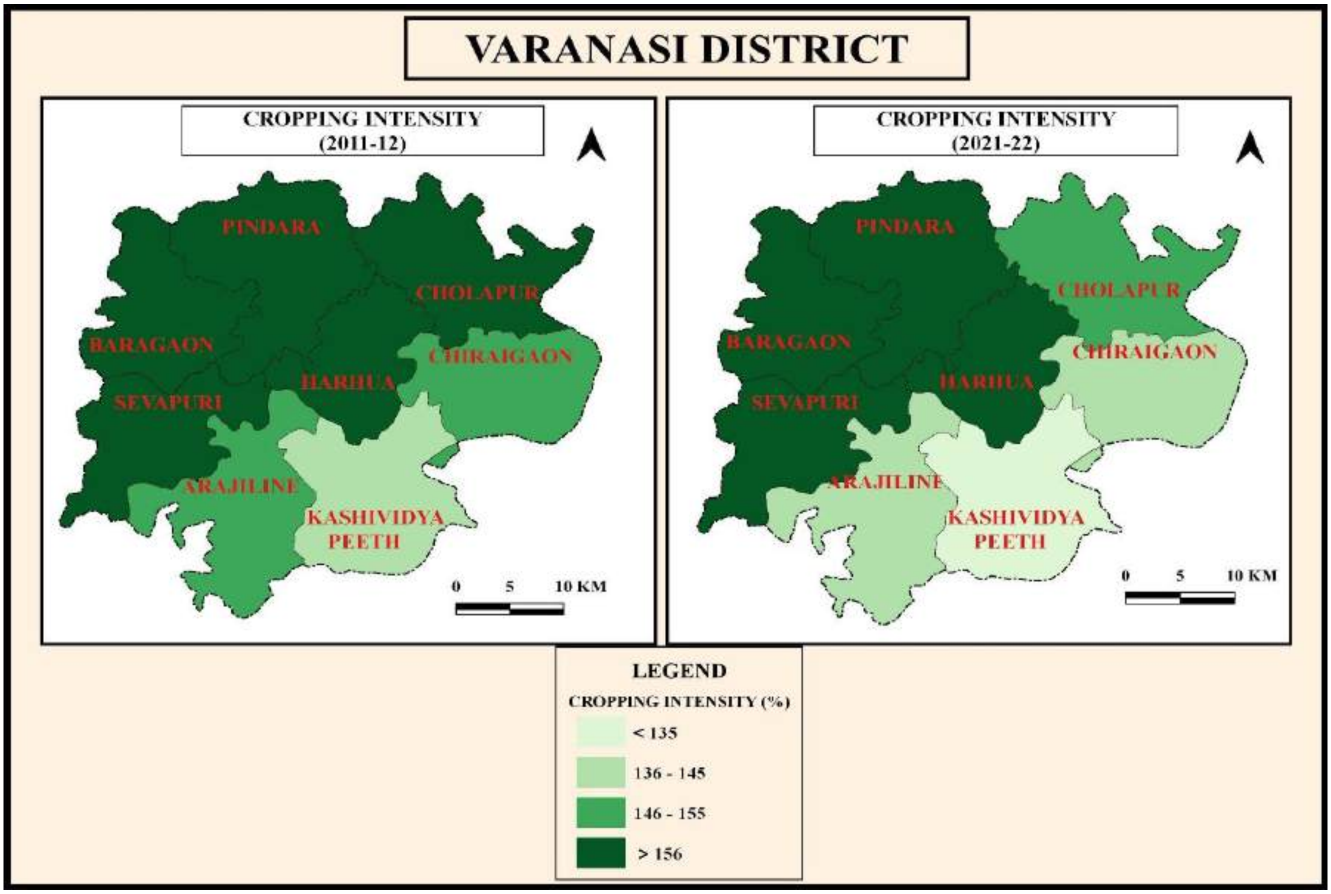
2. Trends and Variations in Cropping Intensity (2011-12 & 2021-22)

During the period 2011–12 to 2021–22, the cropping intensity of Varanasi district, as shown in **Table 2**, exhibited a declining trend, decreasing from 162.12% to 151.09%, indicating a reduction of about 11 percentage points over the decade. This decline suggests a moderate contraction in agricultural land-use efficiency, possibly due to a reduction in multiple cropping practices and the conversion of cultivable land for non-agricultural purposes as a result of urban expansion and infrastructural development. Across the tehsils, cropping intensity declined in almost all areas, with Harhua recording the highest values in both years (181.92% in 2011–12 and 174.75% in 2021–22) owing to assured irrigation facilities and fertile alluvial soils along the Ganga plains. Conversely, Kashi Vidyapeeth exhibited the lowest intensity, dropping from 142.51% to 127.42%, reflecting the growing influence of urbanisation and the conversion of farmland for educational and residential use. Similarly, Arajiline and Chiraigaon experienced noticeable declines from 152.63% to 138.74% and from 154.41% to 140.40%, respectively, which may be attributed to declining water availability and shifts in cropping patterns. Except for Sevapuri, which maintained almost constant intensity (159.29% to 159.10%), all other tehsils showed negative growth. Spatially, cropping intensity varied significantly across the district, ranging from 142.51% (Kashi Vidyapeeth) to 181.92% (Harhua) in 2011–12, and from 127.42% to 174.75% in 2021–22, indicating an increase in inter-tehsil disparity from 39 to 47 percentage points over the decade. Tehsils such as Harhua, Baragaon, and Pindra maintained relatively high cropping intensity due to better irrigation networks and fertile soils, whereas Arajiline, Chiraigaon, and Kashi Vidyapeeth lagged due to semi-urban expansion and decreasing net sown areas. Overall, the observed decline in cropping intensity reflects the combined impact of urban expansion, declining groundwater resources, limited irrigation coverage, and a gradual shift toward less intensive or single-season cropping systems. However, areas like Harhua and Baragaon continue to sustain high intensity through favourable agricultural and environmental conditions.

Table 2:Tehsil-wise Trends in Cropping Intensity (2011–12 &2021–22)

Sl. No.	Tehsil	Gross Cropped Area (ha)		Net Sown Area (ha)		Cropping Intensity (%)	
		2011-12	2021-22	2011-12	2021-22	2011-12	2021-22
1.	**Baragaon**	20448	21218	11956	13125	**171.03**	**161.66**
2.	**Pindra**	27777	28227	16456	18103	**168.80**	**155.92**
3.	**Cholapur**	20401	21145	12781	14143	**159.62**	**149.51**
4.	**Chirai Gaon**	18681	19642	12098	13990	**154.41**	**140.40**
5.	**Harhua**	16911	17248	9296	9870	**181.92**	**174.75**
6.	**Sevapuri**	18621	19148	11690	12035	**159.29**	**159.10**

7.	**Arajiline**	23335	23728	15289	17102	**152.63**	**138.74**
8.	**KashiVidya Peeth**	8625	10459	6052	8208	**142.51**	**127.42**
Varanasi District		**155142**	**161440**	**95698**	**106853**	**162.12**	**151.09**



Sources: Compiled by Author

Figure 2: Map of Cropping Intensity of Varanasi District (2011-12 &2021-22)

3. Changes In Irrigation Intensity (2011-12 & 2021-22)

The irrigation data for Varanasi district between 2011–12 and 2021–22, shown in **Table 3**, reveals notable spatial and temporal variations in irrigation coverage and intensity across different tehsils. During this decade, both net irrigated area and gross irrigated area have increased in almost all tehsils, indicating a general improvement in irrigation infrastructure and utilisation. However, the irrigation intensity, which measures the ratio of gross irrigated area to net irrigated area, has shown a declining trend across all tehsils, suggesting a reduction in multiple cropping or over-dependence on limited water resources.In 2011–12, the net irrigated area in the district was 81,368 hectares, which increased to 96,285 hectares in 2021–22, registering an overall growth of about 18.3%. Similarly, the gross irrigated area rose modestly from 1,29,881 hectares to 1,33,167 hectares during the same period, reflecting a smaller growth of about 2.5%. This disproportionate growth between net and gross irrigated areas has led to a decline in irrigation intensity from 159.62% in 2011–12 to 138.31% in 2021–22, a decrease of around 13.3%.At the tehsil level, Baragaon recorded the highest irrigation intensity (185.88%) in 2011–12, which drastically declined to 153.22% in 2021–22. A similar downward pattern is evident in Pindra (172.71% to 148.51%), Cholapur (155.76% to 137.55%), and Chirai Gaon (155.09% to 130.77%). Even in Harhua, which maintained relatively stable irrigated areas, irrigation intensity fell slightly from 156.30% to 148.81%. The lowest irrigation intensity in both years was observed in Kashi Vidya Peeth tehsil, which declined sharply from 141.11% to 118.13%, indicating lesser water availability or reduced use of irrigation for multiple cropping.

Overall, while the expansion of irrigation coverage in terms of area is a positive development, the declining irrigation intensity points to reduced efficiency and sustainability of irrigation practices. This may be attributed to factors such as the depletion of groundwater resources, irregular rainfall, overreliance on tube wells, and changes in cropping patterns. Thus, the irrigation scenario in Varanasi district, though improved in spatial extent, reflects a growing need for efficient water management and adoption of sustainable irrigation techniques to maintain agricultural productivity in the long run.

Sl. No.	Tehsil	Net Irrigated Area (ha)		Gross Irrigated Area (ha)		Irrigation Intensity (%)	
		2011-12	2021-22	2011-12	2021-22	2011-12	2021-22
1.	**Baragaon**	9344	11588	17369	17755	**185.88**	**153.22**
2.	**Pindra**	13897	16208	24001	24071	**172.71**	**148.51**
3.	**Cholapur**	10544	12069	16423	16601	**155.76**	**137.55**
4.	**Chirai Gaon**	9506	11462	14743	14989	**155.09**	**130.77**
5.	**Harhua**	8933	9341	13962	13900	**156.30**	**148.81**
6.	**Sevapuri**	10193	11670	15477	15613	**151.84**	**133.79**
7.	**Arajiline**	13238	15083	19896	20013	**150.29**	**132.69**
8.	**KashiVidya Peeth**	5475	8335	7726	9846	**141.11**	**118.13**
Varanasi District		**81368**	**96285**	**129881**	**133167**	**159.62**	**138.31**

Table 3: Tehsil-wise Changes in Irrigation Intensity (2011–12 &2021–22)

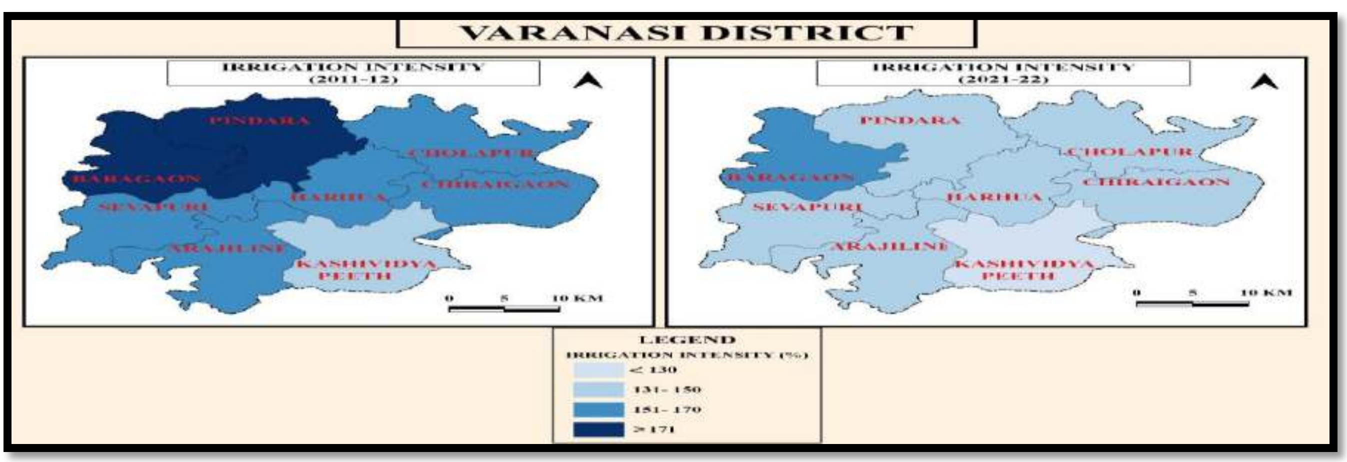
Sources: Compiled by Author

Figure 2: Map of Irrigation Intensity of Varanasi District (2011-12 & 2021-22)

4. Temporal Relationship Between Cropping Intensity and Irrigation Intensity

To fulfil the fourth objective, the study examines whether the relationship between Cropping Intensity and Irrigation Intensity in Varanasi district has changed over time.This analysis is based on block-level data for the years 2011-12 and 2021-22, given below:

Table 4: Tehsil -Wise Cropping Intensity & Irrigation Intensity



(2011-12 & 2021-22)

Sl. No.	Tehsil	Cropping Intensity(%)		Irrigation Intensity (%)	
		2011-12	**2021-22**	**2011-12**	**2021-22**
1.	**Baragaon**	171.03	161.66	185.88	153.22
2.	**Pindra**	168.80	155.92	172.71	148.51
3.	**Cholapur**	159.62	149.51	155.76	137.55
4.	**Chirai Gaon**	154.41	140.40	155.09	130.77
5.	**Harhua**	181.92	174.75	156.30	148.81
6.	**Sevapuri**	159.29	159.10	151.84	133.79
7.	**Arajiline**	152.63	138.74	150.29	132.69
8.	**Kashi Vidya Peeth**	142.51	127.42	141.11	118.13

Sources:Compiled by Author

Before hypothesis testing, the normality of the variables, Cropping Intensity (CI) and Irrigation Intensity (II) for both yearswas assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Given the small sample size (n = 8), the Shapiro–Wilk test was considered more reliable. All variables recorded p-values above the 0.05 threshold (CI 2011–12 = 0.961; CI 2021–22 = 0.978; II 2011–12 = 0.195; II 2021–22 = 0.613), confirming normal distribution. Although II (2011–12) was significant in the Kolmogorov–Smirnov test (p = 0.019), its Shapiro–Wilk result confirmed normality. As a result, parametric techniques such as Pearson correlation and Fisher's r-to-z method were deemed appropriate for further analysis.

Table 5: Pearson Correlation between Cropping Intensity and Irrigation Intensity (2011-12 &2021-22)

Year	Variables Compared	Number	Pearson Correlation (r)	Sig. (p-value)
2011–12	CI (2011-12)& II (2011-12)	8	0.632	0.092
2021–22	CI (2021-22)& II (2021-22)	8	0.852**	0.007

Note:p < 0.01 *indicates a highly significant correlation.*

Sources: IBM SPSS Statistics 27.0.1

Pearson's correlation coefficients were computed separately for the two time periods. In 2011–12, the relationship between CI and II was **moderate and positive** (r = 0.632) but not statistically significant (p = 0.092). By contrast, the 2021–22 data exhibited a **strong and statistically significant** positive correlation (r = 0.852, p = 0.007), indicating an improvement in the CI–II linkage over time. However, Pearson correlation cannot determine whether this increase represents a statistically significant change between the two years.Therefore, Fisher's z-transformation converts the correlations to **z-scores**, which follow an approximately normal distribution and can be compared directly.

1. Each correlation coefficient (r) was converted into a Fisher's z-score using:

$$Z = \frac{1}{2}\ln\left(\frac{1+r}{1-r}\right)$$

where:

- Z= Fisher's transformed value
- r= Pearson correlation coefficient
- ln natural logarithm

Year	Correlation (r)	$\frac{1-r}{1+r}$	$\ln\left(\frac{1+r}{1-r}\right)$	Fisher's z-score
2011–12	0.632	4.4348	1.489	**0.7445**
2021–22	0.852	12.5135	2.527	**1.2635**

Sources: Computed in MS-Excel

2.The difference between these z-scores was then examined using the standard error based on the sample sizes ($n_1 = n_2 = 8$), which falls below the critical value of ±1.96 at the 5% significance level:

$$Z = \frac{Z_1 - Z_2}{\sqrt{\frac{1}{n_1-3} + \frac{1}{n_2-3}}}$$

where,

- Fisher's z-score for correlation in **2011–12**
- Z_2= Fisher's z-score for correlation in **2021–22**
- n_1, n_2= sample sizes for each year (here, **8**)
- $n - 3$= Fisher's correction factor
- Denominator = standard error of the difference between the two z-scores

Component	Value
Z_1 (2011–12)	**0.7445**
Z_2 (2021–22)	**1.2635**
Sample size	**8**
Standard Error	**0.6324**
Final Z-value:	**- 0.82**

Sources: Computed in MS-Excel

The Fisher's test indicates that the observed increase in the correlation between Cropping Intensity and Irrigation Intensity over the decade is **not statistically significant**. Although the numerical value of the correlation increased from moderate to strong, the magnitude of this change is insufficient to conclude that a meaningful structural shift in the CI–II relationship has occurred. This outcome may be partly attributed to the small sample size, which increases the standard error and limits the statistical power of the comparison.

- **Hypothesis Decision**

Based on Fisher's r-to-z test, the study **fails to reject the null hypothesis (H_0)**. Thus, it is concluded that the relationship between Cropping Intensity and Irrigation Intensity in Varanasi district has **not changed significantly** between 2011–12 and 2021–22, despite a visible numerical increase in the strength of correlation.

7. SUGGESTIONS

To ensure sustainable agricultural development, it is crucial to adopt efficient land and resource management strategies across the district. Strengthening sustainable land management requires implementing soil conservation measures, promoting afforestation, and reclaiming degraded or wasteland areas, alongside strict monitoring to prevent the conversion of agricultural land for non-agricultural uses. Improving irrigation efficiency is essential and can be realised by transitioning from traditional flood irrigation to modern micro-irrigation systems such as drip and sprinkler methods, promoting the conjunctive use of surface and groundwater, and encouraging rainwater harvesting and on-farm storage structures. Reviving multiple cropping practices is equally important and can be supported through incentives for short-duration, high-yielding varieties and diversification toward pulses, oilseeds, and vegetables. Ensuring groundwater sustainability demands targeted recharge interventions in over-exploited tehsils like Kashi Vidyapeeth and Cholapur, along with regulating tube-well extraction through community participation. Strengthening agricultural extension services through training on modern techniques, water-saving technologies, and soil health management will further enhance productivity. Promoting integrated farming systemscombining agriculture with horticulture, livestock, and fisheriescan reduce pressure on land while improving farm incomes. Finally, spatially balanced agricultural development should focus on low-performing tehsils such as Kashi Vidyapeeth, Arajiline, and Chiraigaon by improving irrigation networks and restoring cultivable land to ensure equitable and sustainable growth.

8. CONCLUSION

The study shows notable spatial and temporal changes in agricultural land use in Varanasi district between 2011–12 and 2021–22. Forests, pastures, and fallow lands declined, while non-agricultural land expanded due to increasing urbanisation. Although the net sown area increased slightly, the reduction in land sown more than once led to a fall in cropping intensity. Irrigation coverage also increased in area, but irrigation intensity declined across all tehsils, reflecting reduced water-use efficiency and a growing reliance on limited groundwater resources.Correlation analysis showed a positive relationship between cropping intensity and irrigation intensity in both years. Although the correlation increased from moderate in 2011–12 ($r = 0.632$) to strong in 2021–22 ($r = 0.852$), Fisher's r-to-z test revealed that this rise is not statistically significant. This means that, while the association has become numerically stronger, the improvement is not substantial enough to indicate a significant structural change in the relationship between land use and irrigation efficiency.Overall, the findings point to growing pressure on agricultural land, uneven development across tehsils, and the urgent need for sustainable land and water management practices to protect agricultural productivity in Varanasi district.

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