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Crop Diversification in Haryana: An Empirical District-Level Analysis

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Abstract

Crop diversification is an indispensable pre-requisite for agriculture based economies such as the Haryana state to efficiently utilise, regenerate, and conserve limited resources. It is also essential to enhance economic growth and development through the availability of different crops. Therefore, the present study aimed to analyse the district level extent of crop diversification in Haryana with use of different crop diversification indices. To fulfil study objectives, the study used secondary data, taking an average of three years, i.e., 2004-07 and 2018-21. The study focused to analyse the cropping pattern in Haryana. The findings revealed that districts situated in south as well as south-west Haryana had highly crop diversified as compared to northern districts in Haryana.

Keywords: Crop diversification, Crop Combinations, Substitution and Expansion Effect, Composite Entropy Index.

JEL Code: C38, C43, O13, Q18, Q19.

Introduction

Agriculture is the backbone of the Indian economy (Deogharia, 2018). Despite the share of the agriculture sector in national output declining over time in India, nevertheless, the importance of agricultural activities has a considerable significance to the economy since it provides food security to the people and also helps to reduce poverty (Janvry and Sadoulet, 2010; Birthal *et al.,* 2015). The Food and Agriculture Organization (FAO) indicates that India is the largest producer of pulses, jute and milk and the second largest producer of wheat, rice, cotton and sugarcane in the world. Similarly, the economy of the Haryana state also largely depends on the agricultural sector in which the production of wheat and rice pre-dominates (Ohlan, 2012). However, the agrarian structure of the economy of India as well as the Haryana state dominated by small and marginal farmers (Malik and Singh, 2002). According to the Situation Assessment Survey (SAS) conducted by the National Sample Survey Office (NSO), Ministry of Statistics and Programme Implementation (MoSPI) during the NSS 77th Round (January-December 2019) in rural India, there were 89.4 per cent of farmers have less than two hectares of land (Press Information Bureau, 2023). The small and marginal farmers are forced to face the lack of technology, insufficient irrigation facilities, interrupted electricity supply, increasing input costs, issues in minimum support price, storage issues, lack of credit facilities, and increasing cost of livestock feeding (Hegde, 2019). Therefore, these farmers lack in fulfilling their minimum requirements regarding farming as well as household requirements due to a low-level income trap. Ghosh (2021) asserted that merely increasing the productivity of traditional crops, especially cereals, is extremely challenging to increase the income level of small-holding farmers. To strengthen the agriculture sector and improve the well-being of the farmers, during the economic reforms and before the 1990s, there were frequent changes in agricultural policies by the government; however, these policy reforms affected the agricultural sector indirectly, not directly (Chand, 2004). Moreover, to enhance purchasing power as well as food security, it has been proposed that farmers should focus on crop diversification (Shiyani and Pandya, 1998; Radhakrishna and Reddy, 2004; Singh *et al.,* 2006). Presently, policymakers are also focusing on crop diversification to improve the level of agricultural development.

Diversification is a vital aspect of the economy, which helps to transform its structure (Singh *et al.,* 2006). At the macro level, diversification means a deviation from agriculture to industry as well as service sectors. However, the term "diversification" is highly ambiguous when it comes to agriculture because it has different interpretations for different people (Sonawane *et al.*, 2022). At the household level, agriculture diversification denotes transformations in

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crop mix, enterprise mix, and activity mix (Chand, 1996; Deogharia, 2018). Crop diversification indicates the process where traditional crops are substituted for commercial crops. In other words, it is generally viewed as a shift from less remunerative crops to more remunerative crops (Basavaraj *et al.*, 2016). The narrow viewpoint indicates that crop diversification promotes mixed cropping rather than monocropping at the farm level. On the other hand, a broader viewpoint indicates that it is a process in which subsistence crops are substituted by market-oriented cash crops, which have higher returns (Sonawane *et al.*, 2022). It is essential for the economy because the dominance of the monocropping system has severe social, economic, and ecological problems such as a decline in productivity as well as soil fertility, a decline in self-employment levels, and excessive use of groundwater (Chand, 1996). Moreover, after considering consumer needs, it can provide a long-term solution for farmers by providing higher employment opportunities and a higher level of income (Kumar *et al.,* 2012). Further, it is also a procedure where farmers reallocate the available inputs or resources amidst different crops based on comparative advantages (De and Chattopadhyay, 2010). Singh (1976) found that there is a positive relationship between crop diversification and competition, meaning that higher competition leads to higher crop diversification and vice versa (Pal and Kar, 2012). Besides this, Quiroz and Valdes (1995) emphasised that crop diversification is an efficient mechanism to uplift farmers welfare and may reduce the number of suicides among farmers. In a particular region, crop diversification is affected by various factors, mainly geo-climatic conditions, socio-economic situations, and research and development of technology (Hussain, 1997; Mishra and Singh, 2019). Accordingly, it may vary among different regions.

In India, firstly, the post-Green Revolution period witnessed some marks of crop diversification; however, this diversification was characterised as technology-led diversification, where the farmers emphasis was merely on foodgrain crops including rice, wheat, and maize (Deogharia, 2018). Since the 1990s, agriculture in India experienced diversification from traditional foodgrain crops to commercial crops, horticulture crops, and plantation crops (Nadkarni, 1996; Joshi *et al.,* 2004). In 2000, the Government of India announced the National Agricultural Policy (NAP), in which emphasis was placed on the urgent need for the available natural resources, such as water, soil, and bio-resources, to be used efficiently. Consequently, increasing demand in the economy may be fulfilled by considering crop diversification after optimum utilisation of resources. Moreover, since 2013-14, the Department of Agriculture & Farmers Welfare (DA&FW) of the Government of India (GOI) has also implemented a crop diversification policy under the scheme Rashtriya Krishi Vikas Yojana (RKVY); however, the policy focused that water-intensive rice crop should be substituted by less water-intensive crops such as pulses, oilseeds, cotton, etc. (Press Information Bureau, 2022). As being a leading agrarian state in the Indian economy, crop diversification is of the utmost importance for the state of Haryana (Malik and Singh, 2002). The state of Haryana is also known as the *"Food Mine"* of India, in which more than 70 per cent of the population is directly or indirectly based on agricultural activities. Haryana is a self-sufficient state in terms of the production of food and is a major contributor to the central pool annually. Moreover, the Green Revolution had a significant positive impact on the growth of wheat and rice in the state.

As stated above, crop diversification is aimed at cultivating a variety of crops rather than monocropping patterns that have a large number of benefits, such as helping to diversify the financial risk of farmers, enhancing soil fertility, helping in water conservation, enhancing farmers' income with less dependency on any particular crop, promoting biodiversity, reducing environmental impact, and also reducing the need for chemical inputs. Therefore, the present paper is focused on analysing the district-level extent of crop diversification in Haryana.

Data Sources and Methodology

The present study is based on secondary data collected from the Statistical Abstract of Haryana. The analyses considered data at two points in time, taking an average of three years, i.e., 2004–07 and 2018–21. To measure the extent of district-level crop diversification in Haryana, the study considered eleven principal crops, i.e., rice, jowar, bajra, maize, wheat, barley, other cereals, pulses, oilseeds, cotton, and sugarcane. The crop diversification has been computed with the help of seven indices, including the Bhatia index (BI), Jasbir Singh's index (SI), Gibbs and Martin index (GMI), Shannon-Wiener index (SWI), transformed Herfindahl index (THI), Ogive index (OI), and composite entropy index (CEI).

Bhatia Index (BI): According to the Bhatia index, the crop diversification index (CDI) is inversely related to the degree of diversification, i.e., a lower value of CDI indicates higher diversification, and vice versa. In this method, only those crops (*'n'*) are included whose share is more than 10 per cent of the total production.

$$CDI_{BI} = \frac{\text{Percentage of total cropped area under 'n' crops}}{\text{Number of 'n' crops}} \quad (1)$$

Jasbir Singh's Index (SI): The computation process or notion of this method is similar to the Bhatia method, but the main difference is that in this method, those crops (*'n'*) that have a share of equal or more than 5 per cent are included. Therefore, with this method, more crops may be included.

$$CDI_{SI} = \frac{\text{Percentage of total cropped area under 'n' crops}}{\text{Number of 'n' crops}} \quad (2)$$

Gibbs and Martin Index (GMI): This technique takes into account the percentage of cropped area under individual crops (*X*) at a point in time to measure the magnitude of crop diversification. The range of this index lies from 0 to 1, where a higher value indicates higher diversification and vice versa.

$$CDI_{GMI} = 1 - \frac{\sum X^2}{(\sum X)^2} \quad ..(3)$$

Shannon-Wiener Index (SWI): The present study used the Shannon-Wiener index (SWI) to measure the level of crop diversification in Haryana at the district level. Initially, this index was developed by Claude E. Shannon and Norbert Wiener in 1949 (Shannon & Weaver, 1949). A higher value of SWI indicates high diversification or different crops cultivated in that particular region. It is a widely used index that is based on information-theory-based metrics of variety (Neogi and Ghosh, 2022). This index is computed based on the following formula:

$$CDI_{SWI} = -\sum_{i=1}^{N} P_i \ln(P_i) \quad ..(4)$$

Where P_i is the proportion of the particular *i*-th crop to the gross cropped area (GCA), *N* is the number of crops. *ln* is the natural logarithm.

Transformed Herfindahl Index (THI): This index is a modified version of the Herfindahl method (*HI*), which shows the degree of concentration. The *THI* is transformed through the subtraction of *HI* from one (i.e., *THI = 1 – HI)* to avoid any confusion when comparing it with other indices, and the value of this index lies between zero and one. Where zero indicates perfect concentration and a near-one value shows a higher degree of crop diversification.

$$CDI_{THI} = 1 - \sum_{i=1}^{N} P_i^2 \quad ..(5)$$

Ogive Index (OI): This index is used to measure the deviation from the ideal or equal distribution of acreage. In this method, the deviation from the ideal is measured by giving equal proportions to each crop. The computation process is as follows:

$$CDI_{OI} = \frac{\sum_{i=1}^{N}\{P_i - (1/N)\}^2}{\left(\frac{1}{N}\right)} \quad ..(6)$$

Here, *Pi* is the proportion of the particular *i*-th crops to the total cropped area, and N represents the number of crops.

Composite Entropy Index (CEI): The entropy index (EI) measures crop diversification by considering the logarithm character ranging from zero to one, where the highest value represents the highest diversification and vice versa. The upper value of the entropy index is determined by the number of crops and the base value of the logarithm. If the number of crops is higher than the base value of the logarithm, the upper value of the entropy index can exceed one, and vice versa (Basavaraj *et al.*, 2016). Therefore, this method does not provide a standard scale to measure diversification. This limitation has been removed in the modified entropy index through the use of a flexible base of logarithm instead of fixed base values. However, this modified entropy index (MEI) also has the limitation that it measures deviation from an equal distribution among the different existing activities (Gaikwad, 2018). On the other hand, the composite entropy index (CEI) has all the properties of MEI to compute crop diversification, giving weight to a large number of crops (Pal and Kar, 2012). The CEI has two components, such as diversity and the number of crops. The value of this index ranges from zero to one; it increases with higher crop diversification or with a greater number of crops if cropped in a particular region. The computation process for CEI is as follows:

$$CDI_{CEI} = -\left[\sum_{i=1}^{N} P_i \times log_N P_i\right] \times \left\{1 - \left(\frac{1}{N}\right)\right\}$$

or

$$CDI_{CEI} = (MEI) \times \left\{1 - \left(\frac{1}{N}\right)\right\} \quad ..(7)$$

Where P_i is the proportion of area under the particular *i*-th crop, *N* is the number of crops.

Classification of the Intensity of Crop Diversification:

To present a better picture of the level of crop diversification, the study classified crop diversification into three broad categories, considering the mean ($\overline{X}$) and standard deviation (σ) of the CEI, as is under:

High crop diversification = $CEI_i \geq (\overline{X} + \sigma)$

Medium crop diversification = $(\overline{X} - \sigma) \geq CEI_i \leq (\overline{X} + \sigma)$

Low crop diversification = $CEI_i \leq (\overline{X} - \sigma)$

Change in the Cropping Pattern in Haryana:

The cropping pattern reflects the fluctuations in the proportion of cropped areas under different crops at a particular time, which is significantly affected by agro-climatic, technological, and institutional factors (Vaidyanathan, 1980). Moreover, it is also governed by the law of comparative advantage with respect to agro-climate situations (Vyas, 1996). On the other hand, Ghosh (2011) argued that the cropping pattern is the outcome of the adoption of new crops, multiple cropping, the extent and quality of irrigation, the relative cost-benefits of crops, and high-yield variety seeds. Table 1 demonstrates the area and production of the major principal crops in Haryana state. In 2004-07, the highest area sown under cereals was wheat (26.7 per cent) followed by rice, bajra, and jowar. Similarly, in 2018–21, the same crops were also found to be the leading crops in Haryana in terms of sown area. On the other hand, in terms of produced quantity of crops, the highest produced crop in Haryana was wheat (50.6 per cent), which was followed by rice, bajra,

Table 1: Area and Production under Principal Crops in Haryana

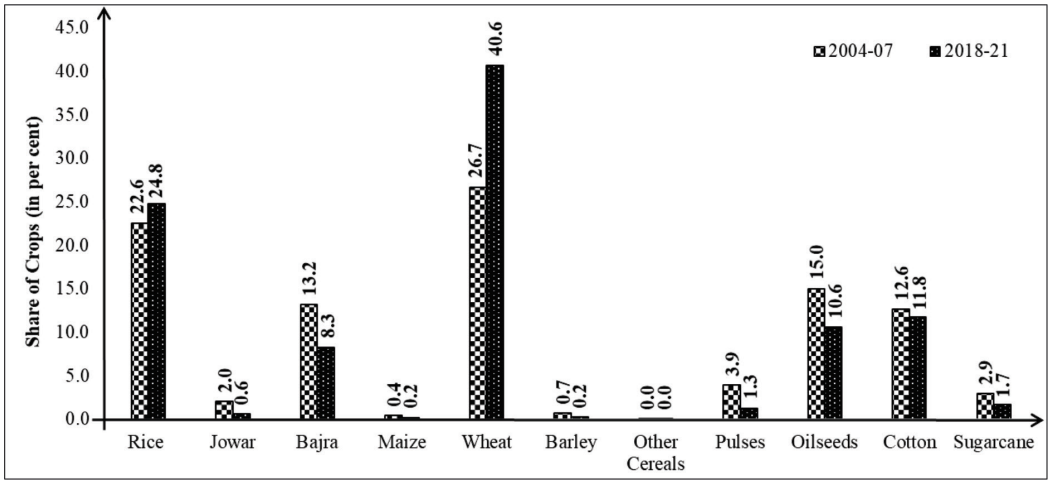
Principal Crops	2004-07		2018-21	
	Area*	Production#	Area*	Production#
Rice	1037.8 (22.6)	3375.0 (18.8)	1510.6 (24.8)	5116.0 (23.9)
Jowar	93.5 (2.0)	26.0 (0.1)	36.2 (0.6)	20.2 (0.1)
Bajra	605.3 (13.2)	834.3 (4.6)	504.1 (8.3)	1141.0 (5.3)
Maize	18.9 (0.4)	30.0 (0.2)	11.8 (0.2)	25.7 (0.1)
Wheat	1228.0 (26.7)	10059.0 (56.0)	2480.4 (40.6)	10755.9 (50.3)
Barley	32.1 (0.7)	84.0 (0.5)	15.1 (0.2)	48.2 (0.2)
Other Cereals	0.5 (0.01)	1.5 (0.01)	1.3 (0.02)	1.3 (0.01)
Total Cereals	**3016.1 (65.6)**	**14410.8 (80.2)**	**4559.4 (74.7)**	**17108.1 (80.1)**
Pulses	180.3 (3.9)	123.1 (0.7)	78.6 (1.3)	75.1 (0.4)
Oilseeds	688.9 (15.0)	839.4 (4.7)	643.8 (10.6)	1248.3 (5.8)
Cotton	579.9 (12.6)	1805.0 (10.1)	717.8 (11.8)	2110.8 (9.9)
Sugarcane	135.1 (2.9)	780.0 (4.3)	102.6 (1.7)	827.0 (3.9)
Total Principal Crops	**4600.2 (100)**	**17957.3 (100)**	**6102.2 (100)**	**21369.4 (100)**

Source: *Computed and Compiled by Author from Statistical Abstract of Haryana (Various issues).*
Note: ** value in 000 ha; # value in 000 tonnes; values in parenthesis indicate relative share to total area or production.*

and barley in both periods. Moreover, except for cereals, the findings confirmed that oilseeds and cotton crops were the topmost commercial crops in Haryana in terms of sown area in 2004–07, whereas the area under cotton and oilseeds was the highest. Whereas, the cotton crop was found to be the most produced commercial crop in Haryana in both periods, followed by oilseeds and sugarcane crops.

It may be clearly observed from Table 1 that in Haryana, the total cereal cropped area drastically increased from 65.6 per cent to 74.7 per cent. However, the share of cereal production in total principal crop production has declined marginally from 80.2 to 80.1 per cent. Over the period, some crops declined in their relative area and production, while others improved. Figure 1 demonstrates that the relative change in the cropped area of selected major principal crops in Haryana. It may be observed that wheat and rice are the dominant crops in Haryana. The combined cropped area of both crops increased from 49.25 per cent in 2004-07 to 65.4 per cent in 2018-21. Whereas, the cropped area of all other crops has declined over time.

Table 2 depicts that over the period the relative growth in production, area, and yield of different principal crops in Haryana. In terms of production, it was found that overall crops were jointly produced with a CAGR of 1.09 per cent



Source: *Computed and Compiled by Authors from the Statistical Abstract of Haryana (Various Issues).*

Figure 1: Shift of sown area under principal crops in Haryana

and the production of total cereals increased with a CAGR of 1.08 per cent. The growth of production of rice was found to be highest among all principal crops, followed by oilseeds, bajra, cotton, wheat, and sugarcane, whereas the growth of production of barley was found to be decreased with the highest negative per cent, i.e., -3.42 per cent, which was followed by pulses, jowar, and maize. Moreover, in terms of the CAGR of the cropped area of the principal crops, the cropped area was highest in other cereals, followed by wheat, rice, and cotton, whereas the area growth of all other crops declined. Further, the study also analysed the crop yield rate or productivity of selected major principal crops, which is a driving force as well as a dominant factor that affects cropping patterns and overall agricultural production. The yield rate may be defined as the ratio of production to cropped area. The growth rate of the cropped crops yield was found to be highest for jowar, followed by the growth rate of bajra, oilseeds, sugarcane, pulses, maize, barley, and rice, whereas the productivity of the remaining other crops decreased. The study observed that the cropping pattern in Haryana was biased towards foodgrain or cereal crops, especially wheat and rice. However, marginal improvement was observed in some non-foodgrain crops such as sugarcane, cotton, and oilseeds; though, cereal crops dominated the cropping pattern in Haryana.

Moreover, the findings also demonstrated that the production growth of bajra, oilseeds, and sugarcane crops was found to be positive, primarily due to a positive yield rate, rather than the growth of cropped areas, which was found to be negative. Despite the increase in the growth of the yield rate, there was a decline in the growth of the production of jowar, maize, barley, and pulses because of the negative growth of the cropped area. Further, the production growth of wheat and cotton was also found to be positive due to the positive growth of cropped area rather than the growth of yield rate. Among all the selected principal crops, rice is the only crop whose growth rate of production was found to be positive due to both area and yield growth rates being positive. Whereas, in the case of other cereals, the production rate was negative, although the growth of the cropped area of other cereals was found to be positive and the yield rate was negative. Overall, the growth of production and area of total cereals as well as total principal crops was found to be positive, whereas the growth of yield was found to be negative.

Since the growth rate of production is determined by the growth rate of area and yield, production growth can be decomposed into the effects of area and yield, as given in the Table 3. Over the period, the production of rice increased by 1741 thousand metric tonnes, out of which 1569.2 thousand metric tonnes increased due to expansion in the cropped area, or area effect, and the remaining 171.8 thousand metric tonnes increased due to an increase in yield growth rate, or yield effect. The production of bajra, oilseeds, and sugarcane crops increased significantly due to the positive yield effect, and the area effect of these crops was found to be negative. The production of jowar, maize, barley, and pulses has decreased due to the negative area effect; however, the yield effect of these crops was found to be positive. On the other hand, the production of wheat and cotton crops has increased due to a positive area effect; however, the yield effect was negative. Whereas the production of other

Table 2: Growth rate (CAGR) of production, area, and yield of principal crops in Haryana, 2004-07 to 2018-21

Principal Crops	CAGR (in per cent)		
	Production	Area	Yield
Rice	2.63	2.37	0.26
Jowar	-1.58	-5.76	4.18
Bajra	1.98	-1.14	3.11
Maize	-0.97	-2.90	1.93
Wheat	0.42	4.49	-4.07
Barley	-3.42	-4.59	1.17
Other Cereals	-1.05	6.44	-7.49
Total Cereals	**1.08**	**2.62**	**-1.54**
Pulses	-3.04	-5.06	2.02
Oilseeds	2.51	-0.42	2.93
Cotton	0.98	1.34	-0.36
Sugarcane	0.37	-1.71	2.07
Total Principal Crops	**1.09**	**1.78**	**-0.69**

Source: *Computed and Compiled by Authors from the Statistical Abstract of Haryana (Various issues).*

cereals has marginally declined due to the negative yield effect, which was higher than the positive area effect. The findings indicate that there has been a change in cropping patterns in Haryana in favour of commercial crops, which have marginally substituted traditional crops. Moreover, the cropping pattern in Haryana was also investigated with the use of the elasticity (E) of gross cropped area *(E = percentage change in area under different crops / percentage change in gross cropped area),* as suggested by Venkataramanan and Prohaladachar (1980) and Ghosh (2011). Here, crops are classified into three categories depending on their value of elasticity. The first category (I) comprises rice, wheat, and other cereal crops with more than one elasticity. The second category (II) includes the cotton crop, whose elasticity was found between zero and one. Further, the third category (III) includes all other remaining crops whose elasticity was less than one, including jowar, bajra, maize, barley, pulses, oilseeds, and sugarcane. The findings explored that the expansion of the cropped areas in Categories I and II was higher than the area that declined in Category III, which reveals the crop substitution in Haryana. It was also found that over the period, the farmers of Haryana substituted marginal crops with an increased sown area under major crops. Moreover, the cropping pattern has been found to be biased towards four crops (i.e., rice, wheat, cotton, and other cereals) in Haryana.

Table 4 demonstrates the substitution as well as expansion effects of different principal crops in Haryana. The substitution effect means a compensative reduction in the gross cropped area of one crop for sowing the other crop, and the expansion effect implies an increase in gross cropped area (Ghosh, 2011). It is worth noting here that both effects also affect the overall cropping pattern of the state. It is found that the area under jowar, bajra, maize, barley, pulses, oilseeds, and sugarcane declined by 361.9 thousand ha due to the substitution effect. In contrast, due to the expansion effect, the area under rice, wheat, other cereals, and cotton crops has increased by 1863.9 thousand ha. Moreover, the findings exhibit that the substitution effect described 16.3 per cent variation in cropped area and the expansion effect explained the remaining 83.7 per cent variation.

Crop Diversification Scenario:

After analysing the change in the cropping pattern in Haryana during the study period, it is vitally necessary to review the district-level crop diversification in Haryana. Tables 5 and 6 depict the crop diversification in Haryana during 2004–07 and 2018–21. The finding of the Bhatia index (BI) revealed that in 2004–07, Hisar district was the most crop diversified district, followed by Jhajjar, Bhiwani, and Rohtak districts, whereas Karnal was found to be the least crop diversified district, followed by Kaithal, Panipat, and Kurukshetra districts. Singh index (SI) demonstrated that Rohtak, Hisar, and Faridabad were highly diversified districts in 2004–07, and Karnal, Kaithal, and Panipat districts were the least diversified districts. The findings of the Gibbs and Martin index (GMI) represent that Hisar, Rohtak, and Jhajjar districts occupied the highest rank in crop diversification, whereas Panipat, Karnal, and Kaithal were the least ranked. The outcomes of the Shannon-Wiener index (SWI) showed that Rohtak, Hisar, and Jhajjar were highly crop-diversified districts in 2004–07, whereas Karnal, Panipat, and Kurukshetra districts were found in the category of least diversification. Further, in the case of the Transformed Herfindahl index (THI), the results were similar to the Gibbs and Martin index (GMI), meaning that Hisar, Rohtak, and

Table 3: Decomposition of increased production into area effect, yield effect, and elasticity (E) of cropped area

Principal Crops	Area Effect*	Yield Effect*	Production Increased*	Area Increased#	E
Rice	1569.2	171.8	1741.0	472.8	E>1
Jowar	-21.3	15.5	-5.8	-57.3	E<0
Bajra	-176.6	483.3	306.7	-101.3	E<0
Maize	-13.0	8.6	-4.3	-7.1	E<0
Wheat	7461.3	-6764.5	696.9	1252.4	E>1
Barley	-48.2	12.3	-35.8	-17.0	E<0
Other Cereals	1.4	-1.7	-0.2	0.8	E>1
Pulses	-79.8	31.8	-48.0	-101.7	E<0
Oilseeds	-68.7	477.5	408.9	-45.0	E<0
Cotton	417.5	-111.7	305.8	137.9	0<E<1
Sugarcane	-219.0	266.1	47.1	-32.5	E<0

Source: Computed by the Authors.
Note: *E-Elasticity; * values in 000 tonnes; # values in 000 ha.*

Table 4: Change in cropping pattern in Haryana: Substitution and Expansion effect during 2004-07 to 2018-21

Crops	Substitution Effect*	Crops	Substitution & Expansion Effect*
Jowar	-57.3	Rice	472.8
Bajra	-101.3	Wheat	1252.4
Maize	-7.1	Other Cereals	0.8
Barley	-17.0	Cotton	137.9
Pulses	-101.7		
Oilseeds	-45.0		
Sugarcane	-32.5		

Source: Computed by the Authors.
Note: ***** *value in 000 ha.*

Jhajjar districts were found to be highly crop diversified districts in 2004–07, whereas Panipat, Karnal, and Kaithal districts were least crop diversification. Moreover, the findings of the Ogive index (OI) revealed that Hisar, Rohtak, and Jhajjar districts were found to be highly crop diversified districts in Haryana in 2004–07, whereas Panipat, Karnal, and Yamunanagar districts had the lowest crop diversification. Furthermore, the findings of the Composite Entropy index (CEI) also demonstrated that Hisar, Rohtak, and Jhajjar districts were also found to be highly crop-diversified districts in Haryana in 2004–07, whereas Mahendragarh, Karnal, and Rewari districts had the lowest crop diversification in Haryana. The outcome also revealed that out of 20 districts, 10 districts, such as Hisar, Rohtak, Jhajjar, Faridabad, Jind, Sonepat, Panchkula, Fatehabad, Bhiwani, and Ambala, were highly crop diversified as compared to the value of crop diversification in overall Haryana.

Table 5: Districts wise status of Crop Diversification in Haryana, 2004-07

Districts	BI	SI	GMI	SWI	THI	OI	CEI
Hisar	21.21	16.28	0.79	1.72	0.79	1.34	0.99
Rohtak	22.40	13.51	0.76	1.78	0.76	1.49	0.98
Jhajjar	21.46	18.58	0.76	1.68	0.76	1.52	0.93
Faridabad	26.27	18.32	0.69	1.54	0.69	2.22	0.88
Jind	29.71	23.66	0.70	1.41	0.70	2.09	0.83
Sonepat	41.15	29.12	0.62	1.30	0.62	2.93	0.79
Panchkula	27.82	22.44	0.72	1.57	0.72	1.86	0.79
Fatehabad	40.11	23.68	0.66	1.33	0.66	2.31	0.72
Bhiwani	22.29	19.21	0.75	1.60	0.75	1.55	0.70
Ambala	43.20	23.51	0.62	1.18	0.62	2.65	0.68
Sirsa	30.81	30.81	0.61	1.23	0.61	2.98	0.57
Yamunanagar	31.32	31.32	0.67	1.29	0.67	2.42	0.57
Nuh	27.61	23.00	0.72	1.52	0.72	2.05	0.55
Panipat	46.25	46.25	0.49	0.92	0.49	4.24	0.53
Gurugram	42.37	29.95	0.64	1.28	0.64	2.75	0.52
Kurukshetra	46.25	46.25	0.57	0.99	0.57	3.10	0.51
Kaithal	46.54	46.54	0.56	0.99	0.56	3.47	0.45
Rewari	46.21	46.21	0.56	1.01	0.56	3.47	0.45
Karnal	48.16	48.16	0.54	0.87	0.54	3.75	0.42
Mahendragarh	45.73	45.73	0.58	1.02	0.58	3.64	0.40
$\bar{X}$	**35.34**	**30.13**	**0.65**	**1.31**	**0.65**	**2.59**	**0.66**

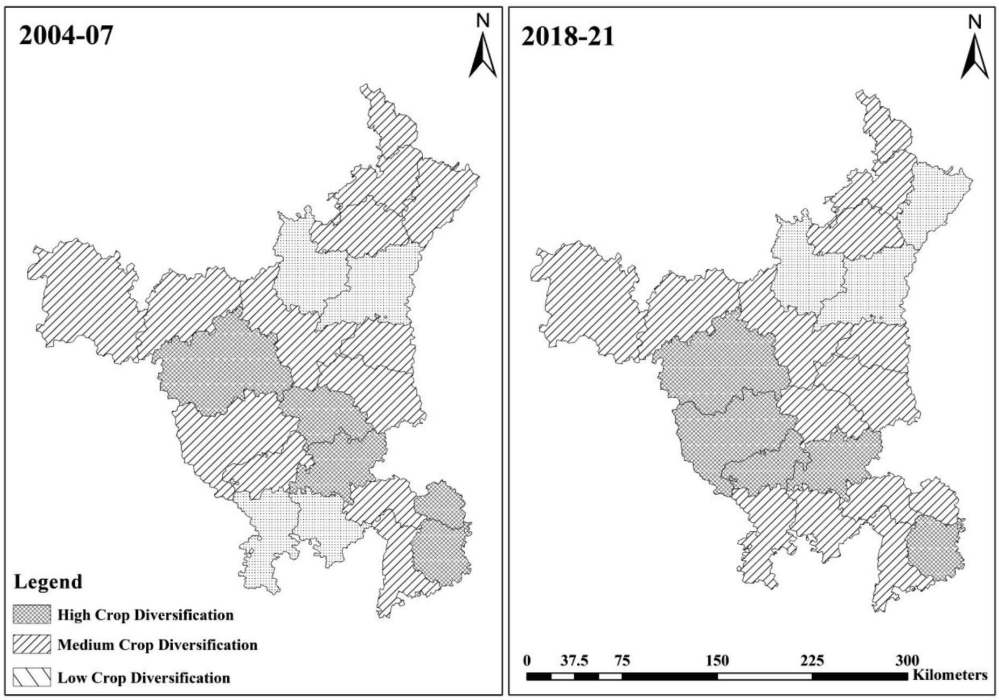
Source: Authors own estimations. $\bar{X}$ *: Mean*

In contrast, in 2018–21, the findings of the Bhatia index (BI) revealed that Bhiwani district was the most crop diversified district, followed by Hisar, Jhajjar, and Ambala districts, whereas Kaithal was found to be the least crop diversified followed by Karnal, Panipat, and Kurukshetra districts. The findings of the Singh index (SI) demonstrated that Rohtak, Bhiwani, and Nuh were highly diversified districts in 2018–21, and Kaithal, Karnal, and Panipat districts were the least diversified districts. Further, the findings of the Gibbs and Martin index (GMI) indicate that Bhiwani, Charkhi Dadri, Hisar, and Jhajjar districts occupied the highest rank in crop diversification, whereas Kaithal, Karnal, and Panipat districts had the least crop diversification in Haryana. The outcomes of the Shannon-Wiener index (SWI) showed that Bhiwani, Charkhi Dadri, Hisar, and Palwal were highly crop diversified in 2018–21, whereas Kaithal, Karnal, Panipat, and Kurukshetra districts were found in the category of least diversification. Moreover, in the case of the Transformed Herfindahl index (THI), the results were similar to the Gibbs and Martin index (GMI), meaning that Bhiwani, Charkhi Dadri, Hisar, and Jhajjar districts were found to be highly crop diversified districts in 2018–21, whereas Kaithal, Karnal, and Panipat districts had the least crop diversification. Furthermore, the findings of the Ogive index (OI) revealed that Bhiwani, Charkhi Dadri, Hisar, and Jhajjar districts were highly crop diversified districts in Haryana in 2018–21, whereas Panipat, Kaithal, Karnal, and Sonepat districts had the lowest crop diversification. On the other hand, the findings of the Composite Entropy index (CEI) also demonstrated that Bhiwani, Charkhi Dadri, Hisar, and Palwal districts were also found to be highly crop diversified districts in Haryana in 2018–21, whereas Kaithal, Karnal, Yamunanagar, and Jind districts had the lowest crop diversification in Haryana. The outcome also revealed that out of 22 districts, 10 districts, such as Bhiwani, Charkhi Dadri, Hisar, Palwal, Jhajjar, Gurugram, Rohtak, Nuh, Rewari, and Faridabad, were highly crop diversified as compared to the average value of crop diversification in Haryana. Further, the study also graphically demonstrated the district-level crop diversification in Haryana between

Table 6: Districts wise status of Crop Diversification in Haryana, 2018-21

Districts	BI	SI	GMI	SWI	THI	OI	CEI
Bhiwani	22.21	18.79	0.78	1.67	0.78	1.37	0.99
Charkhi Dadri	23.18	23.18	0.77	1.61	0.77	1.51	0.97
Hisar	22.42	22.42	0.75	1.58	0.75	1.73	0.96
Palwal	27.42	22.55	0.72	1.56	0.72	2.03	0.95
Jhajjar	22.80	19.29	0.74	1.56	0.74	1.91	0.95
Gurugram	29.51	23.39	0.71	1.44	0.71	2.20	0.91
Rohtak	36.94	18.41	0.71	1.52	0.71	2.23	0.89
Nuh	27.47	18.93	0.70	1.51	0.70	2.26	0.87
Rewari	29.82	24.38	0.71	1.39	0.71	2.19	0.79
Faridabad	30.39	24.18	0.70	1.37	0.70	2.12	0.75
Sonepat	45.09	45.09	0.58	1.10	0.58	3.57	0.69
Fatehabad	31.05	24.61	0.66	1.26	0.66	2.47	0.66
Ambala	22.88	30.51	0.62	1.18	0.62	2.40	0.64
Sirsa	29.52	24.54	0.69	1.33	0.69	2.23	0.63
Mahendragarh	29.25	24.14	0.70	1.35	0.70	1.95	0.62
Panchkula	29.24	29.24	0.67	1.40	0.67	2.15	0.61
Kurukshetra	45.36	45.36	0.58	1.04	0.58	2.70	0.61
Panipat	47.00	47.00	0.56	0.96	0.56	3.88	0.60
Jind	42.72	31.75	0.61	1.14	0.61	2.74	0.53
Yamunanagar	32.72	32.72	0.60	1.06	0.60	2.54	0.38
Karnal	47.85	47.85	0.54	0.88	0.54	3.69	0.37
Kaithal	48.21	48.21	0.53	0.87	0.53	3.77	0.29
$\bar{X}$	**32.87**	**29.39**	**0.67**	**1.31**	**0.67**	**2.44**	**0.71**

Source: Authors own estimations. $\bar{X}$: Mean



Source: Created by Authors from Table 5 and 6 through ArcGIS (ArcMap 10.3).

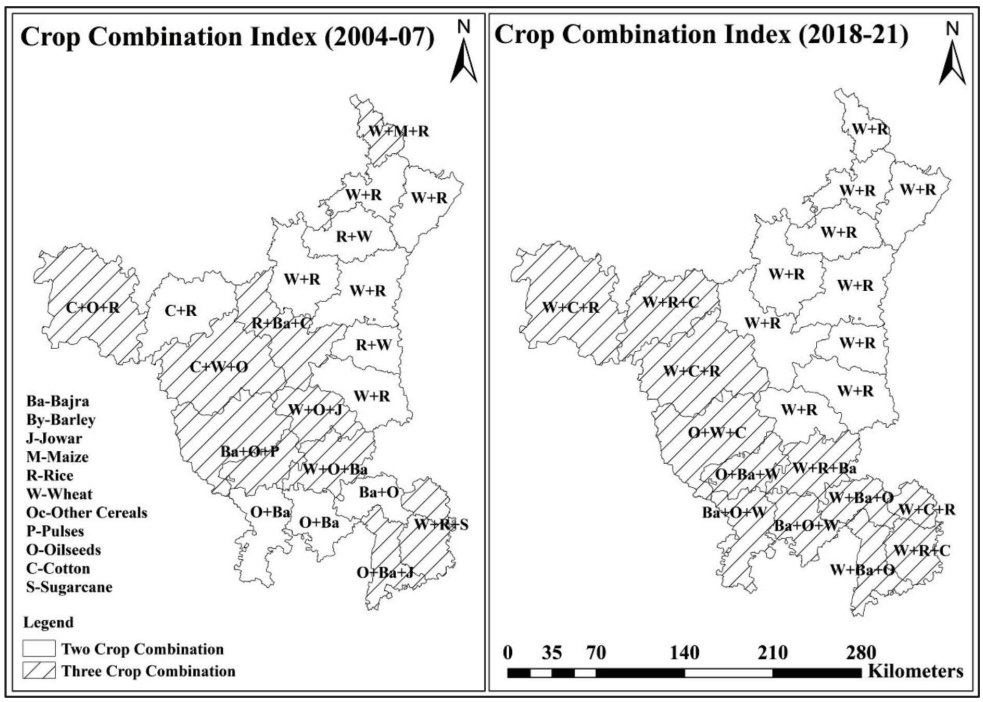
Figure 2: Level of Crop Diversification in Haryana in Haryana in 2004-07 and 2018-21

2004–07 and 2018–21 (see Figure 2). Moreover, the level of crop diversification is also divided into three levels, i.e., highly crop diversified districts, medium crop diversified districts, and low crop diversified districts, based on the criteria of mean and standard deviation from the mean as mentioned in the methodology section.

Further, to check whether the increase in crop diversification had any effect on cropping patterns among districts in Haryana, the study constructed a crop combination index for both periods based on Doi's method (see Figure 3). Here, the crop combination means the number of crops cultivated in different seasons on the same agricultural land, which also reflects the behaviour of farmers towards the cultivation of various crops and affects the available physical as well as climatic factors, i.e., irrigation facilities, soil fertility, market connectivity, rainfall, availability of pesticides, etc. (Biswas, 2020). The findings revealed that most of the districts have merely two or three crop combinations. In 2004–07, out of 20 districts, nine found three crop combinations, and other districts found merely two crop combinations. On the contrary, in 2018–21, out of 22 districts, 12 had three crop combinations, whereas the other 10 had merely two crop combinations. Further, the area under different combinations of crops had more than 70 per cent of the gross cropped area in the majority of the districts in both periods. In terms of the fluctuations in the crop combinations, it is found that in three districts, namely Jind, Panchkula, and Rohtak, the combinations declined from three to two combinations. Among the four districts, the crop combinations had increased from two to three, including Fatehabad, Gurugram, Mahendragarh, and Rewari districts. Moreover, seven districts, namely Ambala, Kaithal, Karnal, Kurukshetra, Panipat, Sonepat, and Yamunanagar, had the same two crop combinations in both periods, i.e., wheat and rice. Whereas, among eight districts, including Bhiwani, Charkhi Dadri, Faridabad, Hisar, Jhajjar, Nuh, Palwal, and Sirsa, there were three crop combinations in both periods. Consequently, it is visible that most of the districts situated in north Haryana had two crop combinations, i.e., wheat and rice, in both periods. Whereas, districts situated in south Haryana as well as south-west Haryana had three crop combinations. In south and south-west Haryana, three crops, i.e., cotton, oilseeds, and bajra, were majorly cropped in addition to wheat and rice. The findings of the crop combination index also confirmed that the districts situated in south and south-west Haryana increased the level of crop diversification, whereas north Haryana had a monocropping pattern.

Conclusion and Policy Implications:

Haryana being an agricultural economy, crop diversification is an indispensable pre-requisite to efficiently utilise the limited resources available in the state. The findings found that wheat and rice were the dominant crops in Haryana, where sown areas under both crops have increased, and the cropping pattern was biased towards the



Source: Created by Authors from Table 8 through ArcGIS (ArcMap 10.3).

Figure 3: Crop combination index in Haryana during 2004-07 to 2018-21

major four crops, including wheat, rice, cotton, and other cereals, which had substituted for other crops. On the other hand, at disaggregated level, the study examined the extent of district level crop diversification over the period and revealed that districts situated in south as well as south-west Haryana had highly crop diversified as compared to northern districts in Haryana. Over the period, it was found that crop diversification had increased in Bhiwani, Charkhi Dadri, Rewari, and Mahendragarh districts, and declined in Faridabad, Rohtak, and Yamunanagar districts, whereas other districts remained same level of crop diversification. On the other hand, the findings of the crop combination index also confirmed that the districts situated in south and south-west Haryana increased the level of crop diversification, whereas north Haryana has a monocropping pattern. Based on the findings, the study suggests that there may be a need for crop diversification among less diversified districts to efficiently utilise, regenerate, and conserve available limited resources, such as groundwater, which have declined over time in Haryana.

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