Plant Archives Vol. 25, Supplement 2, 2025 pp.640-646 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.supplement-2.079

MARGINAL IMPACT OF DETERMINANTS AFFECTING CROP DIVERSIFICATION IN THE STATE OF RAJASTHAN USING TOBIT REGRESSION APPROACH

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(Date of Receiving : 19-04-2025; Date of Acceptance : 26-06-2025)

ABSTRACT

The present study is done in Rajasthan state covering all the districts to analyze the crop diversification index in the two time periods viz., 2021-22 and 2022-23 using Hirschhman Herfindahl Index and Simpson Diversification Index. The study revealed that Sirohi district of Rajasthan has shown the highest diversification followed by Pali district in both the time period taken in the study. Further using Tobit regression approach, the impact of various determinants affecting crop diversification was analysed. The Tobit regression was used in the present study because the dependent variable used in the study was continuous and left censored and therefore, the lower bound in the study was set at 0.1 and hence 2 of the observations were left censored and rest of the 31 were left uncensored Total 33 observations were here as before March 2023, 33 districts were here in Rajasthan state. The study revealed that except factors like fertilizer consumption, area not available for cultivation and fertilizer consumption all the other determinants were significant at 5 per cent level of significance. The study further revealed that total cropped area, hybrid seed production is significantly as well as positively affecting the SID values implicating that with 1 per cent increase in the total cropped area and hybrid seed production, the diversification index increases by 2.8 and 1.7 per cent respectively.
***Keywords*:** Crop diversification, Simpson diversification index, Tobit regression approach, Hirschamn Herfindahl index, Sustainability.

Introduction

The world population has increased more than 8 billion and the climate is also a threat to the food production, therefore it is a prime need to solve the issue using various sustainable agriculture. Despite of increase in the productivity the agriculture sector is facing so many challenges such as increase in the risk to climate change, water scarcity, soil degradation, etc, (Chand and Parappurathu, 2012; Pingali, 2012). There should be enhancement in the approaches that leads to sustainable farming practices to achieve the security in the food supply. One such approach is crop diversification. According to (Mehra *et al*., 2022) crop diversification is introducing the new variety of crops in the cropping system or addition of few other crops in the existing system. It not only leads to risk minimization but also helps in the increase in the income of the farmers, conservation of natural resources, etc. Further it can also help in reducing the level of poverty and protects small and marginal farmers (Alam, 2004; Sharma, 2005; Kumar and Gupta, 2015). Therefore, crop diversification is one of the leading and known factor that is helpful to maintain sustainability in the food production system. The present study is done in the Rajasthan state to show that how crop diversification can be effective in the arid climatic conditions. But, crop diversification in arid and semi-arid climates (like that of Rajasthan) can be challenging due to several factors such as:

- **Limited water availability**: Arid and semi-arid regions often have limited water resources, which makes it difficult to grow a variety of crops.
- **Soil quality**: The soil in these regions is often poor in quality, which limits the types of crops that can be grown.

- **Pest and disease pressure**: Arid and semi-arid regions are often prone to pests and diseases, which can make crop diversification difficult.
- **Climate variability**: These regions are often characterized by unpredictable weather patterns, which can make crop planning and diversification challenging.
- **Lack of infrastructure**: Arid and semi-arid regions often have limited infrastructure, which can make it difficult to transport and market a diverse range of crops.
- **Socioeconomic factors**: Smallholder farmers in arid and semi-arid regions often lack the resources and knowledge to diversify their cropping systems.
- **Limited market**: These regions often have limited market for some crops that can be grown.

Crop diversification

Crop diversification is defined as the practice of growing a variety of crops in a particular area over a specific period of time rather than focussing on the cultivation of a solo crop. Therefore, it helps to minimize the risk associated with the market price, improves the condition of soil, enhances biodiversity, reduces reliance on chemical inputs, helps to decrease the build up of pest and diseases, etc. Diversification is further approached under the following heads: Horizontal diversification or intercropping which involves expanding the crop base by growing them simultaneously or within the same growing season, while, In vertical diversification different crops are gown over different seasons or rotations such as crop rotation, relay cropping, sequential cropping,

Benefits from Crop Diversification

- Increases Farmers' income: Agricultural crop diversification is an important stress- relieving option for the economic growth of the farming community. Crop diversification and inclusion of the new varieties can be one of the important technologies in increasing the farmers' income to a certain extent.
- Increases natural biodiversity and productivity: It can also increase natural biodiversity, strengthening the ability of the agro ecosystem to respond to these stresses. It is enhancing plant productivity, quality, health and nutritional value and/or building crop resilience to diseases.
- Reduces the risk of total crop failure: It reduces the risk of total crop failure as different crops will respond to climate scenarios in different ways.

Crop diversification in India

India has 328 million hectares of land from which 123 million ha comes under forest, pasture and waste area which in unsuitable for cultivation. Fifty million ha land has access to irrigation water and over two third of the land cultivable comes under rainfed cultivation (Hegde, 1990). Onto that India has welcomed new cropping systems in the view to achieve higher productivity as well as to increase income of the farmers (Jadhav, 2015). For instance, rice and wheat cropping system from north, groundnut in Gujarat, sugarcane in north, chickpea in southern states, arhar in north western states, soybean in Madhya Pradesh, Mustard in Rajasthan, etc is sown (Paroda, 2022). Green revolution was one such example that shifted cropping pattern in India from less profitable crops to more profitable crops such as wheat and rice with the help of introducing high yielding verities, increased irrigation, chemical fertilizers, etc (Sonawane, 2022).

Table 1: Various crops grown in the country and the percentage change

Crops	Area (mha) 2021-22	Area (mha) 2020-21	Percentage change	Crops	Area (mha) 2021-22	Area (mha) 2021-22	Percentage change
Rice	46.38	45.77	0.01	**Soybean**	12.27	12.92	-0.05
Wheat	30.47	31.33	-0.02	**Sunflower**	0.28	0.23	0.21
Nutri cereals	22.65	24.12	-0.06	**Cotton**	11.91	13.29	-0.10
Jowar	3.81	4.38	-0.13	**Jute**	0.69	0.66	0.04
Bajra	6.70	7.65	-0.12	**Sugarcane**	5.15	4.85	0.06
Maize	10.04	9.89	0.01	**Tobacco**	0.36	0.40	-0.10
Tur	5.05	4.72	0.06	**Lentil**	1.42	1.47	-0.03
Gram	10.91	10.00	0.09	**Groundnut**	5.75	6.01	-0.04
Rapeseed and mustard	8.06	6.70	0.20				

Source: Agriculture statistics at glance (2021-22)

The following table suggests that from 2020-21 to 2021-22 area of crops such as wheat, nutri cereals, jowar, bajra, soybean, cotton, tobacco, lentil, cotton and groundnut has decreased, whereas, rice, maize, tur, gram, rapeseed and mustard, sunflower, jute and sugarcane area has increased. As the existing cropping pattern is diverted more towards sugarcane, rice, maize, etc which has created the problem of depletion of ground water in the north western parts of the country. Therefore, to enhance water use efficiency, sustainable development and farmer's income, government had introduced crop diversification program through Rashtriya Krishi Vikas Yojna scheme since 2013-14 to shift the area from water depleting to water saving crops such as pulses, oilseeds, etc (PIB, 2022).

Therefore, studying crop diversification in Rajasthan can provide insight into the potential benefits of diversifying crop production in a semi-arid region and arid regions. Additionally, crop diversification also helps to increase income for farmers by providing a variety of crops to sell in the market. Understanding the challenges and successes of crop diversification in Rajasthan can inform similar efforts in other regions facing similar climate and soil conditions.

Materials and Methods

Study area and Data

The current study is based on secondary data on parameters like numbers of crops grown, their area of cultivation, hybrid seed distribution, gross irrigated area, forest area, rainfall, fallow land, etc for the year 2022-23 for each district of Rajasthan during kharif season. The secondary data was collected from variety of sources such as Rajasthan Agriculture Statistics, district survey reports, census book, etc. Various crop growing in Kharif season in different districts of Rajasthan including their net sown area in the year 2022 (revised advanced estimates) was collected and crop diversification index was calculated.

Statistical tools used

(A) Herfindahl Index

It was for the first time used by Theil (1967). The Herfindahl index can be used to measure the diversity of crops in a specific area, region or country. It is calculated by summing the squares of the percentage of total area used for each crop. A lower Herfindahl index in crop diversification would indicate a more diverse set of crops being grown, with no one crop taking up a large percentage of the total area, while a higher index would indicate that a smaller number of crops make up a larger percentage of the total area, indicating less crop diversification indicating that Herfindahl Index decreases with an increasing diversification.

$$\textit{Herfindahl Index} = \sum_{i=1}^{N} p_i^2$$

Where: Pi is the proportion of ith crop area grown in that particular area and N is the total no. of area covered by all the crops grown in that area.

(B) Simpson Index of Diversification

The Simpson index, also known as the Simpson diversity index, is another measure of diversity that is often used to evaluate crop diversification. It is considered to be a better indicator than the Herfindahl index for several reasons: a. The Simpson index takes into account both the number of different crops and their relative abundance, whereas the Herfindahl index only considers the relative abundance of different crops. b. The Simpson index ranges from 0, indicating no diversity, to 1, indicating complete diversity. This allows for a clear and intuitive interpretation of the results, whereas the Herfindahl index is a number that ranges from close to 0 to 10,000, not as easy to interpret. c. The Simpson index is more sensitive to changes in the distribution of crop types within a landscape. This means that small changes in crop diversity can be detected more easily using the Simpson index, providing a more accurate picture of crop diversification. d. The Simpson index can be used to evaluate both the overall diversity of a landscape and the diversity within individual fields or plots. This allows for a more detailed analysis of crop diversification. The formula for the Simpson index of crop diversification is:

$$\textit{Simpson index} = 1 - \sum_{i=1}^{N} p_i^2$$

Where: D is the Simpson index and p is the proportion of the total area used for each crop. The result ranges from 0 to 1, with 1 indicating complete diversity (every plot has a different crop) and 0 indicating no diversity (all plots have the same crop).

Tobit Regression analysis

To assess the determinants of crop diversification tobit regression was used to establish the relationship between various variables that are taken in the study viz., forest area, gross cropped area, gross irrigated area, rainfall, fertilizer consumption, etc. These independent variables were selected based on the review of literature done on the existing research works. Simpson index of diversification was considered as the dependent variable. Tobit regression

was used as the dependent variable is continuous and censored between the values of 0 and 1. The Tobit regression model is given as:

$$y_i^* = x_i'\beta + \varepsilon_i$$
$$y_i = 0 \ \ if \ \ y_i^* \leq 0$$
$$y_i = y_i^* \ if \ \ y_i^* > 0$$

where y_i^* is the degree of income diversification with a value that lies between 0 and 1, β is the parameter to be estimated, x is the matrix of the independent variables. The empirical tobit model identifies the determinants of the crop diversification at district or macro level as flows:

$$Y = \beta_{0+}\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \varepsilon_i$$

where:

Y= *SID*
X_1= total cropped area
X_2= HYVP seed distribution
X_3= gross irrigated area
X_4=forest area
X_5=area under bajra monocrop
X_6= farm harvest price (FHP) of bajra
X_7=rainfall
X_8=area not available for cultivation
X_9= fertilizer consumption

Here, total cropped area, gross irrigated area, forest area, area under bajra crop and area not available for cultivation is in hectares, seed distribution is in numbers, farm harvest price is in rupees, rainfall is in mm and fertilizer consumption is in m tonnes.

Results and Discussions

Crop Diversification indices

Crop diversification index using HHI (Hirschman Herfindahl index) index and SID (Simpson diversification index) was calculated for all the districts of Rajasthan during the two different time periods viz, 2022-23 and 2021-22 in table 2. The value of SID ranges from 0 to 1 as discussed earlier. From the table it can be concluded that during the year 2021-22 the highest SID value of 0.80 was shown in Sirohi district followed by Pali with a value of 0.69, whereas lowest crop diversification was shown in Dholpur (0.06). It is evident from the table that Sirohi and Pali districts of Rajasthan again remained on the highest position in terms of diversification of crops with a value of 0.76 and 0.71, respectively.

Table 2 : Crop Diversification Indices

Districts	*HHI Index Values*		*SID Values*	
	2022-23	*2021-22*	*2022-23*	*2021-22*
Ganganagar	0.85	0.83	0.14	0.17
Hanumangarh	0.60	0.57	0.39	0.43
Bikaner	0.43	0.43	0.56	0.57
Churu	0.53	0.52	0.46	0.48
Jhunjhunu	0.74	0.71	0.25	0.29
Alwar	0.70	0.66	0.29	0.34
Bharatpur	0.60	0.63	0.39	0.37
Dholpur	0.95	0.94	0.04	0.06
Karoli	0.79	0.79	0.20	0.21
S Madhopur	0.51	0.51	0.48	0.49
Dausa	0.74	0.77	0.25	0.23
Jaipur	0.66	0.64	0.33	0.36
Sikar	0.81	0.79	0.18	0.21
Nagaur	0.50	0.48	0.49	0.52
Jodhpur	0.39	0.39	0.60	0.61
Jaisalmer	0.54	0.55	0.45	0.45
Barmer	0.88	0.92	0.11	0.08
Jalore	0.54	0.65	0.45	0.35
Sirohi	0.23	0.20	0.76	0.80
Pali	0.28	0.31	0.71	0.69
Ajmer	0.44	0.43	0.55	0.57
Tonk	0.35	0.47	0.64	0.53
Bundi	0.35	0.35	0.64	0.65
Bhilwara	0.39	0.31	0.60	0.69

Rajsamand	0.72	0.73	0.27	0.27
Udaipur	0.55	0.59	0.44	0.41
Dungarpur	0.38	0.40	0.61	0.60
Banswara	0.34	0.37	0.65	0.63
Chittor	0.37	0.37	0.62	0.63
Kota	0.72	0.77	0.27	0.23
Baran	0.70	0.78	0.29	0.22
Jhalawar	0.74	0.75	0.25	0.25
Pratapgadh	0.59	0.62	0.40	0.38

Crop diversification index using HHI (Hirschman Herfindahl index) index and SID (Simpson diversification index) was calculated for all the districts of Rajasthan during the two different time periods viz., 2022-23 and 2021-22 in table 2. The value of SID ranges from 0 to 1. It can be witnessed from the table that Sirohi has shown highest diversification index in both the years. The values of index for Sirohi were 0.76 in 2022-23 and 0.80 in 2022-23. Following the highest diversified district, Pali also exhibits high SID value of 0.71. The two districts in Rajasthan which showed lowest diversification were Dholpur and Shri Gnaganagar with the values of 0.04 and 0.14, respectively. The districts such as Barmer had shown increase in the diversification from 0.08 in 2021-22 to 0.11 in 2022-23. Furthermore, districts such as Karoli, Madhopur and Jaisalmer had shown no significant changes in diversification values in both the years with the SID index value of 0.21, 0.48 and 0.45, respectively. The research study in generic sense had shown that southern parts of Rajasthan like Sirohi, Pali, Tonk, Banswara has more value of diversification as compared to western parts of Rajasthan which includes Barmer, Jaisermer, Dholpur, etc. The reason behind the scenario was more varied climate in the Aravali range of mountain with better supply of water in southern part as compared to the western arid Rajasthan. The Southern Aravali range also offers diverge range of ecosystem like hills, wetlands and forest cover. Topographic variations in this range contributes to more diversification as compared to the arid environment which is mainly dominated by desert ecosystem. The table 3 below has classisfied the districts of Rajasthan in the level of high, medium and low diversification (Challa *et al*., 2019).

Table 3 : Classification of districts based on level of diversification

Level of Diversification	SID Values	Districts
Low level	0.00-0.38	Dholpur, Ganganagar, Dausa, Karauli, Sikar, Alwar, Udaipur, Kota, Baran, etc
Medium level	0.39-0.63	Jodhpur, Ajmer, Jalore, Bikaner, etc
High level	0.63 and above	Sirohi, pali, Tonk, Bundi, etc

Tobit Regression

The Tobit estimates of the determinants of the crop diversification is analysed in table 4. While analysing the tobit model the lower bound was set at 0.1 which censored those values which were less than 0.1, hence 2 of the observations were left censored and rest of the 31 were left uncensored. The table indicates that except factors like fertilizer consumption, area not available for cultivation and fertilizer consumption all the other determinants are significant at 5 per cent level of significance. The study further revealed that total cropped area, hybrid seed production is significantly as well as positively affecting the SID values implicating that with 1 per cent increase in the total cropped area and hybrid seed production, the diversification index increases by 2.8 and 1.7 per cent respectively. Fertilizer consumption is also positively related with the crop diversification but it is statistically insignificant at 5 per cent as well as 1 per cent level of significance. Forest area is negatively and significantly correlated with the diversification as it reveals that with the increase in the area of forest the area available for the cultivation decreases. Further bajra is the main kharif season crop that is grown in almost all parts of the Rajasthan state and if the FHP of bajra increases farmers from different district will focus more on bajra cultivation which will lead to monocropping and hence the diversification will decrease.

Table 4 : Determinants of crop diversification in all districts of Rajasthan

SID	Coef.	Std. Err.	P>t
TOTAL CROPPED AREA	0.334*	1.05e-07	0.028
HYVP SEED DISTRIBUTION (QT)	0.253*	4.87e-06	0.017
GROSS IRR AREA	-0.026*	2.80e-06	0.027
FOREST AREA	-0.063	5.15e-07	0.067
AREA UNDER BAJRA	-0.025*	0.0000192	0.001
FHP BAJRA	-0.033*	0.0000552	0.023
RAINFALL (mm)	-0.256*	0.0001611	0.041
AREA NOT AVAL FOR CULLTIVATION	-0.015	3.42e-07	0.651
FERTILIZER CONSUMP kharif (mt)	0.042	4.99e-06	0.985
_cons	.3417962	0.2051691	0.109
/Sigma	.149655		.1098912
Number of observations = 33			
LR $chi^2(9)$ = 17.65			
Prob > chi^2 = 0.0395			
Log likelihood = 12.869173			
Pseudo R^2 = -2.1820			
2 left-censored observations at SID <= .1			
31 uncensored observations			
0 right-censored observations			

*Figures were statistically significant at 5 per cent level of significance

The tobit regression results showed that total cropped area and HYV seed distribution positively and significantly influence crop diversification in Rajasthan. Whereas, rainfall, gross irrigated area, area under monocrop (bajra), and FHP of bajra showed a significant negative effect. Fertilizer use, forest area, and uncultivable land came out to be statistically insignificant.

Table 5: Significance level of factors affecting crop diversification

Variable	Coefficient	Significance
Total cropped area	0.334*	Significant at 5% level
HYP seed distribution	0.253*	Significant at 5% level
Gross irrigated are	-0.026*	Significant at 5% level
Forest area	-0.063	Insignificant
Area under monocrop	-0.025*	Significant at 5% level
Rainfall	-0.256*	Significant at 5% level
Fertilizer application	0.042	Insignificant
Area not available/suitable for cultivation	-0.015	Insignificant
Farm harvest price of monocrop	-0.033*	Significant at 5% level

Conclusion

The study highlights the extent of crop diversification using HHI and SID index in all the districts of Rajasthan in the two time periods viz, 2022-23 and 2021-22 to show which district of Rajasthan has more diversification than the other. Further the motive of the study is to show that how the various determinants of crop diversification is affecting it using the Tobit regression approach. The Tobit model was used because the dependent variable used in the study (SID) is having few censored values. The values were left censored and hence the lower bound was fixed at 0.1. The regression approach shows the elasticities of each parameter used in the study which reveals that how the diversification changes with the change in the independent variable considered in the present study.

References

Adjimoti, G.O., & Kwadzo, G.T.M. (2018). Crop diversification and household food security status: evidence from rural Benin. *Agriculture & Food Security*, **7**(1), 1-12.

Aheibam, M., Singh, R., Feroze, S.M., Singh, N.U., Singh, R.J., & Singh, A.K. (2017). Identifying the determinants and extent of crop diversification at household level: evidence from Ukhrul District, Manipur. *Economic Affairs*, **62**(1), 89-95.

Alam, J. (2004). Analysis. of crop sector diversification in Bangladesh. *Journal of the Bangladesh Agricultural University*, **2**(2), 375-386.

Basavaraj, N.D., Gajanana, T.M., & Satishkumar, M. (2016). Crop Diversification in Gadag District of Karnataka §. *Agricultural Economics Research Review*, **29**(1), 151-158.

Chand, R., & Parappurathu, S. (2012). Temporal and spatial variations in agricultural growth and its determinants. *Economic and Political Weekly*, 55-64.

Gebiso, T., Ketema, M., Shumetie, A., & Leggesse, G. (2023). Crop diversification level and its determinants in Ethiopia. *Cogent Food & amp; Agriculture*, **9**(2), 2278924.

Kumar, S., Kumar, S., Chahal, V.P., & Singh, D.R. (2018). Trends and determinants of crop diversification in Uttar Pradesh. *Indian J. Agric. Sci*, **88**, 1704-1708.

Mehra, P., Roy, S., & Pande, R. (2022). 8.15 Enhancing Farmer's Income by Promoting Crop Diversification in Cotton Regenerative Agriculture System. *Sustainable Agricultural Innovations for Resilient Agri-Food Systems*, 402.

Pingali, P.L. (2017). The Green Revolution and crop biodiversity. In *Routledge handbook of agricultural biodiversity* (pp. 213-223). Routledge.

Sharma, H.R. (2005). Agricultural development and crop diversification in Himachal Pradesh: understanding the patterns, processes, determinants and lessons. *Indian Journal of Agricultural Economics*, **60**(1).