Chapter-3

A Temporal Analysis of Crop Diversification in Punjab's Agriculture

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Chapter 3
A Temporal Analysis of Crop Diversification in Punjab's Agriculture

3.1 Introduction

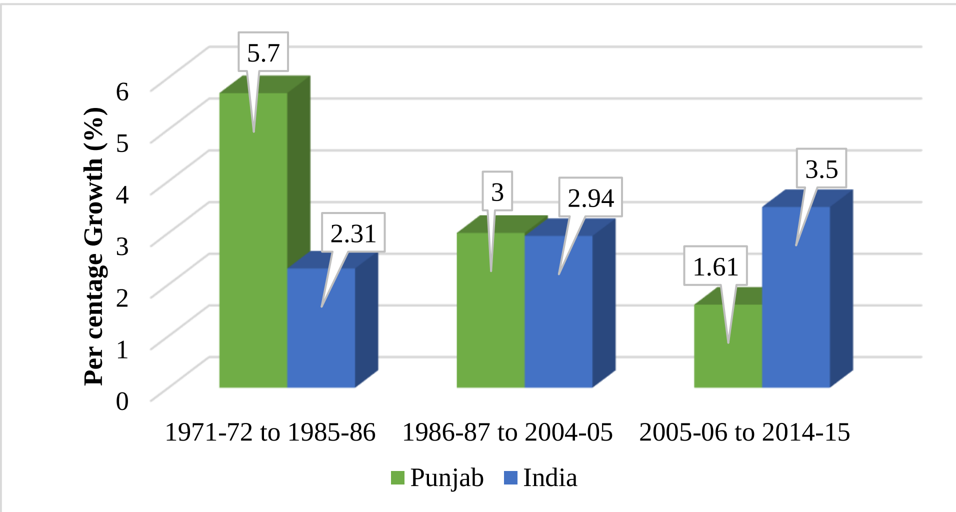
The emergence of green revolution in developing countries during 1960s' has given rise to conventional agricultural system. The farmers applied excessive synthetic inputs such as chemical fertilizers, insecticides, fungicides and pesticides to increase in productivity and profitability on the farms (Eicher, 2003). This highly commercialized agriculture system has replaced with mono-cropping system instead of traditional diversified cropping system in developing countries (Hutagaol, 2006). As result several serious distortions has arisen in the economy (Sajjad & Prasad, 2014). Recently, there is growing concern among researchers about the ill effects of conventional agricultural production system in developing nations (Chand, 1999; Sidhu, 2002; Singh, 2004; Singh & Sidhu, 2004; Ray et al., 2005; Sharma et al., 2005; Ghosh et al., 2015; Singh, 2015).

A number of studies proposed that crop diversification is an appropriate strategy to neutralize these challenges and hurdles faced by developing nations (Mahmud et al., 1994; Rahman, 2009; Kasem & Thapa, 2011; Michler & Josephson, 2017). As per Food and Agriculture Organization (FAO, 2012) crop diversification is an effective method to deal with the issues of nutrition security, ecological management, employment generation, poverty alleviation and sustainable agricultural growth. Similarly, International Food Policy Research Institute and many other studies have also supported the above argument that higher growth in agricultural income can be achieved by crop diversification (Vyas, 1996; Joshi et al., 2004, Joshi et al., 2006; Taffesse et al., 2011).

Indian agriculture in general and Punjab's agriculture in particular, is dealing with the complexity originated from practicing conventional agriculture system (Ghosh et al., 2015). Due to pursuance of conventional agricultural practices, more than 3/4th of the cultivated area faces the problem of water table deficit (Hira et al., 2004; Sarkar, 2011). Additionally, around 2.23 lakh hectares land area out of 50.36 lakh hectares is facing various soil related issues (Punjab State Land Use Board, 2015).

Undoubtedly, the state has achieved a spectacular performance in agriculture. The state's agricultural GDP growth rate was 5.7 percent per annum from 1971-72 to 1985-86, which was much greater as compared to the national agricultural growth rate, which stood at about 2.31 percent per annum. However, during 1985-86 to 2004-05 Punjab's economy started to lag with growth rate touching 3 percent per annum (Figure 3.1). During 2005-06 to 2014-15, it further slides down to only 1.6 percent per annum as against 3.5 percent per annum at all India level. Thus, to overcome such kind of challenges focus has to be shifted towards changing the cropping pattern in the state.

Figure 3.1: Growth rate of agriculture in Punjab and India



Source: Gulati et al. (2015)

Several policy makers and researchers have given emphasis on this falling phase of agricultural productivity in Punjab, and they tried to explored extent and degree of diversification in agriculture and sources of its growth (Kurosaki, 2003; Kumar & Gupta, 2015; Das & Mili, 2012; Dasgupta & Bhaumik, 2014; Banerjee & Banerjee, 2015; Basavaraj et al., 2016). However, still state farmers are facing various difficult phases such as falling productivity growth, environment degradation due to conventional practices. Even-though the government continuously strives for various crop diversification policies, yet serious steps have not been taken to preserve state's natural resources which are degraded by commercial agricultural system. Being a small and one of the agriculturally rich state, it is important to resolve such serious matter. A number of studies have been conducted on this issue; but an important aspect that has received; little attention is the decomposition analysis of sources of agriculture growth. As noted above, the present study put an effort in this direction. This chapter proposes to fill this gap by focusing on decomposition analysis to know the sources which are responsible for this change in growth.

In this chapter, the time-series dataset is used from 1960-61 to 2017-18 collected from DES (Directorate of Economics and Statistics) of India and Economic and Politically Weekly Research Foundation. This study has followed the well-developed approaches (Boyle & McCarthy, 1997)[1] and (Dhindsa & Sharma, 1995)[2] for the analysis of performance of cropping pattern in state. The questions that arise in this chapter are:- What are the recent trend followed in farming sector by farmers in Punjab?; Are they specilazing in a few crops or diversified?. Therefore, this chapter of the study focuses on (i) to explore the trend and pattern of crop diversification in Punjab, and (ii) to identify the factors those determine crop diversification.

[1] This approach is used for inter-temporal movements of crops.

[2] This is followed for explore the sources of change in patterns (Decomoposition Approach).

This study contributes to the literature in following way. Firstly, it assess the decomposition analysis to compute the major sources of agrarian growth in the state which will further help in making appropriate policies to increase agricultural growth rate in the state. Secondly, it pursue a new methodology which has not been utilized in the literature before. All the existing studies had growing interest in the statistical tools to measure degree of diversification. The present study applied the Kendall's Coefficient of Concordance Index in order to test the degree of consistency or concordance between the ranks of the crops in different years. The main purpose to use rank of the area under crops is to identify the top performing crops in a competitive farming.

The remaining of the chapter is structured as follows. Section 3.2 provides the factual background in terms of relevant descriptive statistics. Section 3.3 represents the sources of data and empirical methodology framework. Section 3.4 presents the main results; while the last Section 3.6 presents conclusions and policy implications.

3.2 Background and Literature

Various studies are available on the importance of diversification in the agriculture sector. Generally, in literature diversification has divided into two parts:-vertical diversification and horizontal diversification. The vertical diversification refers to diversification between agricultural and allied activities whereas horizontal diversification means a mix or adds on of more crops to the existing pattern (Haque et al., 2010; Banerjee & Banerjee, 2015; Chakrabarty, 2015). A number of studies have shown that the agricultural sector has gradually diversified from low value to higher value return crops. The countries like Sri Lanka, India, South Asia, and others have achieved better food security at the national level based on their comparative advantage in producing primary products; and have specialized in the production of either rice, wheat or maize. Nepal, Bhutan, and Pakistan have shown lower diversity because these countries still have a deficit in food-grain production, forcing them to concentrate on the cereals, particularly rice, maize, and wheat to achieve their goal of self-sufficiency in food grains, while the country Bangladesh has attained their self-sufficiency condition in food grain but they still concentrate on only rice crop (Joshi et al., 2004, Rahman, 2009; Mahmud et al., 1994; Mermut, 2012). Studies which have particularly examined the change in cropping pattern in Indian context point out that the highest proportion of food grain to the total cropped area is in the north-east region, north-west region, east region, and central region, while the southern region is the leader in production of non-food grain crops (Kumar & Gupta, 2015). The structure of crop diversification in Indian agriculture has rapidly changed after green revolution. The state of Karnataka has higher crop diversification in agriculture followed by J&K, Uttarakhand, Rajasthan, Maharashtra, Uttar Pradesh, Andhra Pradesh, Madhya Pradesh, and Tamil Nadu. The states like Chhattisgarh, Tripura, and Odisha have been observed among the less crop diversified states. The northern dry zone is more diversified than the northern transitional zone. The prevailing institutional structure in these states has ensured that the government price and trade policies are powerful key to influence the changing cropping pattern conditions in different states (Kalaiselvi, 2012; Rao et al., 2006; Roy & Thorat, 2008). Further, the studies which have examined within country changes in cropping pattern have shown that the cropping pattern had changed from a subsistence level to commercial level. The states like West Bengal, Gujarat, Punjab and West Punjab have shown a weakening trend in the area under cultivation of pulses whereas an increase area under cultivation of the higher return value crops such as cereals rice, wheat etc. (Shiyani & Pandya, 1998; Singh & Sidhu, 2004; Kurosaki, 2003; Sharma, 2005; Acharya et al., 2011; Chakraborty, 2012; Dasgupta & Bhaumik, 2014; Sajjad & Prasad, 2014). Meanwhile, the state of Karnataka has shown an expansion in area under cultivation of horticultural crops and pulses as compared to oilseeds, cereals, fibre and other crop groups (Basavaraj et al., 2016).

3.3 Material and Method

Secondary data have been used to explain the cropping pattern and consistency of the crops. Data has been collected on Area (000' ha), Production (000' tone), and Yield (kg/ha) from Directorate of Economics and Statistics (DES) of India and data on Farm Harvest Price (Rs. in per Quintal) from Economic and Political Weekly Research Foundation (EPWRF). Further, the data on the variables such as fertilizers per hectare (NPK), number of market per hectare (MARKT), road length in Kms. per hectare (ROAD), percentage of urban population (UB), number of tractor per hectare (TRC), rainfall in mm (RAIN), cropping intensity (CI), and intensity of irrigation (IRRINTY) have been collected from VDSA (Village Dynamics in South Asia) dataset generated by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). The absolute value of considered variables in the study is transform in terms of natural logarithm. One of the reasons behind selection of data from 1960-61 onwards is due to the emergence of various structural transformations such as green revolution in that decade. For the temporal analysis data has structured for the variables viz., area, production and yield under leading crops. This study concentrations on major 11 crops, viz., wheat, maize, cotton, paddy, total oilseeds, sugarcane, potatoes, total pulses, barley, onion, and millets (Bajra); together accounting for 93 per cent of the total cropped area.

3.3.1 Exponential growth rate and quadratic growth rate

To evaluate the growth rate both exponential form of growth rate and quadratic form of growth rate has computed. The exponential form is chosen because this gives a constant rate of increase or decrease per unit of time. The initial form of exponential function can be written as:

$$Y_t = AB^t v_t \qquad (3.1)$$

For convenient, the multiplicative form of the model has been transformed into additive form by taking natural logarithmic and the final form Equation (3.1) is as follows:

$$y_t = a + t.b + u_t \qquad (3.2)$$

where $y_t = \log$ of $area, production,\ and\ yield$

a = intercept

t = time (in year)

u_t = error term and a is the intercept

here, b gives the instantaneous (at a point in time) growth rate and not the compound (over time) growth rate. Therefore, the compound growth rate is calculated using the following formula:

Compound Growth Rate (CGR) = Antilog (b -1)×100

In exponential form assumes constant growth rate, thus it is hard to determine any acceleration or deceleration in the growth rate over time. To overcome this problem log-quadratic form is used. The log-quadratic form can be written as follows:

$$y_t = a + bt + ct^2 + u_t \qquad (3.3)$$

If the estimated value of *c* has significantly (t-ratio is used as test statistics) positive value, it will depict acceleration in growth rate and in case of significantly negative value that will indicate deceleration in growth rate. The combination of t and t^2 on the right-hand side of Equation *(3.3)* may generate a problem of multi-collinearity. This problem is avoided by the normalization of time in mean deviation using the average mean of time, by setting t = *1,2,3…….*which allows the time *(t)* and its square *(t^2)* to become orthogonal.

To know the magnitude of crop diversification, there are number of statistical tools by which diversification can be measured such as Simpson Index, Entropy Index, Modified Entropy Index and many more; and each of these indices have its own limitations (Shiyani & Pandya, 1998). In spite of their differences, these indices give more or less similar results. In this chapter Herfindahl Index (HHI)[3] and Composite Entropy Index (CEI)[4] (Indices are computed based on the share of area under crop to gross cropped area) have been computed to measures of diversification. HHI has more frequently applied for estimation because of its simplicity in computation, whereas CEI applied because it possess all the desirable properties and also fulfill all the limitation of other indices. Since the index uses $-log_N P_i$ as weights, it gives higher weights to lower quantity and less weight to higher quantity (Khatun & Roy, 2015).

3.3.2 Rank analysis

Further, to study the pattern of the crops according to the ranks of their area covered over the period of time, crops are ranked in descending order. In order to test the degree of consistency or concordance between the rankings of the crops in different years, Kendall's coefficient of concordance[5] has been worked out which is denoted by the symbol *'W'*, it is a non-parametric statistic. It is widely used to find out the degree of association among several *k* (here *k* is time period) sets of ranking of *n* objects or individuals (*n* is number of crops). The *'W'* statistics value in Equation (3.4) examine the consistency of ranking of crops over the years where *k* is the number of raters (58 years from 1960- 61 to 2017-18), n is the number of

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[3] Herfindahl Index (HHI) is computed as: $HHI = \sum_{i=1}^{n} \left(\frac{P_i}{\sum_{i=1}^{n} P_i} \right)^2$ where, n is the total number of crops and P_i represents area proportion of the i^{th} crop in total cropped area. HHI is bounded by zero and one. When it takes value one means there is complete concentration and approaches zero indicate diversification is perfect. Former this index was applied by Sharma (2005).

[4] Composite Entropy Index (CEI) = $-(\sum_{i=1}^{N} P * log_N P_i) * \{1 - (1/N)\}$ since index uses $-log_N P_i$ as weights, it assign more to lower quantity and less weight to higher quantity. HHI index is a measure of concentration but CEI is diversification Index.

[5] Kendall (1984), The problem of m rankings statistics: Theory and Practice, 133-135.

individuals or objects (here the number of crops 11). If there are two set of rankings than it normally employ Spearman's coefficient of correlation, but if there are more sets of rankings, Kendall's coefficient of concordance have to used. Kendall's *W* ranges from $0 \leq W \leq 1$, where *1* represents perfect concordance or complete agreement, *0* represents no agreement. Kendall's coefficient of concordance can be computed as follows.

$$W = \frac{12s}{k^2(n^3 - n)} \tag{3.4}$$

where, $S = \sum_{i=1}^{n} \sum (R_{i} - \bar{R})^{2}$

S is the sum of squares of the deviations of sum of ranks of crops *(Ri)* from the mean of the ranks $\bar{R}$. ($\bar{R} = k\,(n + l)/2$) Then the coefficient of concordance *(W)* was worked out from the *S* as follows.

3.3.3 Index of rank concordance

The inter-temporal mobility of ranking of crops has construct by using rank concordance index proposed by Boyle and McCarthy (1997). This estimate tries to capture the change in the rankings as reflected by Kendall's index of rank concordance. In particular, they proposed a multi-annual version *(RCt)* and a binary version *(RCat)* of the measure. Multiannual version is defined as follows:

$$RC_t = \frac{Var[\sum_{t=0}^{\tau} R(Y_{it})]}{Var[(T+1)^* R(Y)_{i0}]}$$

(3.5)

In Equation (3.5), $R(Y)_{it}$ = Actual ranking of the i^{th} crop area in total area under all crops in year *t;* $R(Y)_{i0}$ = Actual ranking of the i^{th} crop area in the initial year *0* in terms of total area under all crops; *(T+1)* = Number of years for which data are used in calculating the index.

The binary measure, on the other hand can be obtained by considering the ranks in year *t* and *0* is given as follows:

$$RC_{at} = \frac{Var[R(Y)_{it} + R(Y)_{i0}]}{Var[2^{*}R(Y)_{i0}]}$$

(3.6)

Clearly, the multi-annual measure, extending over the entire period, contains all possible pairs of years for which the binary measure could be computed.

3.3.4 Decomposition of sources of growth

Since the green revolution period, cropping pattern has been changing in agriculture because of changes in its sources of growth. In this regard, there is a need to compute the major sources of agrarian growth in the state which would further help in making appropriate policies to increase agricultural growth rate in the state. Many researchers have used decomposition analysis to recognise the major sources of agriculture growth. In the literature, broadly two versions of decomposition methods have been debated: first is additive version of decomposition and second is multiplicative version of decomposition. A systematic approach to study the decomposition of agricultural growth was initially given by (Minhas & Vaidyanathan, 1965) who followed additive version of decomposition. They considered change in total production of agriculture pertaining to changes in four aspects which were area, yield, cropping pattern and interactions among the later two. However, as (Sagar, 1980) extended the "decomposition to seven component form, which included decomposing agricultural output at prevailing prices into three components, viz,. area, yield, price and their interactions (Area-Price, Area-Yield, Yield-Price and Area-Price-Yield)." In this study factor additive version of decomposition analysis; is used to find the total change in agricultural production over time, formerly this method applied in Punjab by (Dhindsa & Sharma, 1995).

$$Q_t - Q_0 = A_t \sum C_{it} Y_{it} P_{it} - A_0 \sum C_{i0} Y_{i0} P_{i0} \;\; \boldsymbol{or}$$

$$\Delta Q = Q_t - Q_0 = (A_t - A_0) \sum C_{i0} Y_{i0} P_i + A_0 \sum C_{i0} (Y_{it} - Y_{i0}) P_i + A_0 \sum (C_{it} - C_{i0}) Y_{i0} P_i$$
$$+ (A_t - A_0) \sum (C_{it} - C_{i0}) Y_{i0} P_i + (A_t - A_0) \sum C_{i0} (Y_{it} - Y_{i0}) P_i$$
$$+ A_0 \sum (C_{it} - C_{i0}) (Y_{it} - Y_{i0}) P_i + (A_t - A_0) \sum (C_{it} - C_{i0}) (Y_{it} - Y_{i0}) P_i$$

(3.7)

In Equation (3.7), $Q_0 = \mathrm{A}_0 \sum \mathrm{C}_{i0} \mathrm{Y}_{i0} \mathrm{P}_{i0}$ *and* $Q_t = A_t \sum C_{it} Y_{it} P_{it}$ presents the total value of agricultural output (at constant prices P_i) of initial and final period correspondingly. A_0 and A_t are total cropped areas in the initial and final year respectively. $C_{i0} = \left(A_{i0} / A_0 \right), C_{it} = \left(A_{it} / A_t \right)$ and Y_{i0}, Y_{it} denote the share of area under each crop to total cropped area and yield of (i^{th}) crop in the initial and current year respectively. P_i are base year farm harvest price. Here, $(A_t - A_0) \sum C_{i0} Y_{i0} P_i$ represent the simply area effect; $A_0 \sum C_{i0} (Y_{it} - Y_{i0}) P_i$ is yield effect; $A_0 \sum (C_{it} - C_{i0}) Y_{i0} P_i$ represent cropping pattern effect. $(A_t - A_0) \sum (C_{it} - C_{i0}) Y_{i0} P_i$ is represent area and cropping pattern effect; $(A_t - A_0) \sum C_{i0} (Y_{it} - Y_{i0}) P_i$ represent area and yield effect; $A_0 \sum (C_{it} - C_{i0}) (Y_{it} - Y_{i0}) P_i$ represent cropping pattern and yield effect. $(A_t - A_0) \sum (C_{it} - C_{i0}) (Y_{it} - Y_{i0}) P_i$ is area, yield and cropping pattern.

3.3.5 Determinants of crop diversification

To determine the factors the factors those affect crop diversification following specification (Deschenes & Greenstone, 2007) is applied:

$$Y_{it} = \alpha_i + \sum_{i=1}^{N} \rho_i (a_i \times T) + \sum_{j=1}^{M} \beta_j x_{it} + + \varepsilon_{it}$$

(3.8)

where, Y_{it} is log of crop diversification in district i in year t. α_i represents the district fixed effect. Further, $(a_i \times T)$ is a district-specific exponential time trend to switch for the district-specific heterogeneity in crop diversification due to others technological change. ρ_i is coefficient of time trend across districts. The β*'s* are coefficients of different x_{it} explanatory variables in districts *i* in year *t.*

3.3.6 Measures of crop diversification

Several indices have been used to measures the diversity in cropping system such as Herfindahl Index, Simpson Index, Entropy Index and many more. Each index have its own merits and demerits. In spite of their differences, these indices give more or less similar results. In this study, Composite Entropy Index has been constructed as earlier followed by (Shiyani & Pandya, 1998).

$$CEI_{it} = -\left(\sum_{i=1}^{N} P * log_N P_i\right) * \{1 - (1/N)\} \tag{3.9}$$

where, CEI_{it} is the diversity in cropping system; p_i is the area share of crop i in the total cropped area. The range of the index lies between 0 & 1; 0 represents complete specialization, whereas 1 represents complete diversification. Since index uses $-log_N P_i$ as weights, it assign more to lower quantity and less weight to higher quantity.

3.4 Results

3.4.1 Shift in cropping pattern

The cropping pattern in Punjab has changed; if the area under cultivation of the crops is seen over time. Throughout the study period, most of the crops have lost their area under cultivation except for wheat and paddy. Table 3.1 represents the shift in cropping pattern in

Punjab. The results show that share of area under wheat to total cropped area has increased from 30.26 percent in 1960-61 to 44.07 percent in 2017-18. Paddy, which consisted of only 4.80 percent of total cropped area in 1960-61 has been able to augment its share to 36 per cent in 2017-18. The area under both these crops have expanded at the cost of the area under crops such as maize, cotton, oilseed, sugarcane, millets, pulses, etc. The share of area under pulses has drastically reduced from 55.05 percent in 1960-61 to a negligible 0.37 percent in 2017-18. The area under cotton in 1960-61 was 9.45 percent of the total cropped area, which has declined 2.24 percent in 2017-18. The area under cotton has shown remarkable fluctuation during the study period, which may be the consequence of pest attack, problem of water logging in the cotton belt and adoption of Bt cotton in latter period. The total cropped area has augmented from 47.32 lakh hectare in 1960-61 to 78.96 lakh hectare in 2017-18. But, this expansion in area was limited to wheat and paddy crops only. Thus, the increase in the area and production of cereals has grown at a faster rate after 1966-67, whereas, the reverse trend is observed in the case of pulses. The continuous decline in the area under the pulses took place at the expense of increase in the area under cereals, particularly of wheat and paddy.

Table 3.1: Proportion of area under each crop to total cropped area in Punjab (000' hectare)

Year	Wheat	Paddy	Cotton	Maize	SUG	TOS	Potatoes	TP	Barley	Onion	Millet
1960-61	25.79	4.09	8.05	5.89	3.33	0.14	2.40	46.92	1.15	0.00	2.23
1965-66	40.28	7.31	10.77	9.60	5.84	0.37	4.17	16.09	1.67	0.01	3.89
1970-71	47.58	8.07	9.83	11.49	6.11	0.23	2.65	8.57	1.18	0.02	4.28
1975-76	45.36	10.55	10.36	10.73	5.88	1.18	2.12	8.15	2.23	0.07	3.38
1980-81	47.79	20.02	11.61	6.42	4.21	0.67	1.21	5.74	1.10	0.02	1.21
1985-86	49.46	27.24	9.01	4.13	3.36	0.68	1.23	3.57	0.79	0.02	0.49
1990-91	49.81	30.67	10.05	2.88	1.64	0.39	1.54	2.27	0.56	0.03	0.17
1995-96	46.96	31.86	10.82	2.49	3.00	0.57	1.98	1.59	0.58	0.02	0.12
2000-01	47.62	36.49	8.48	2.31	1.21	0.83	1.69	0.84	0.45	0.02	0.07
2005-06	48.37	36.85	8.47	2.06	1.14	1.05	1.17	0.45	0.26	0.11	0.07
2010-11	48.31	38.96	7.71	1.83	0.74	0.89	0.96	0.29	0.17	0.11	0.04
2015-16	48.44	41.08	3.94	1.59	0.60	2.25	1.24	0.62	0.12	0.12	0.00
2017-18	49.45	40.43	2.52	2.34	0.54	2.87	1.17	0.42	0.11	0.12	0.03

Source: Author's Calculation by using data from Directorate of Economics and Statistics

Note: SUG= Sugarcane, TOS=Total Oil Seeds, TP = Total Pulses

3.4.2 Exponential and quadratic growth rate

Table 3.2 presents the exponential growth along with acceleration and deceleration growth in area, production, and productivity of the crops. It found that only wheat, paddy, potato, and onion crops have experienced positive exponential growth under area, while all other crops have shown negative exponential growth rate during the study period. Further, results show that agricultural sector is affected by deceleration in area, production and productivity growth. This deceleration in growth occurs due to pursuing monocropping pattern. The results are found to be similar as reported by Singh et al. (1998); Sidhu and Johl (2002) in their studies. Expansion of irrigation facilities, new technology, risks in cultivation of the other perishable crops, low productivity and market performance, low yields in pulses and unsatisfactory prices are found to be the factors responsible for the emergence of monocroping as major structural change in the state (Deshpande & Chandrashekar, 1982; Grewal & Bhullar, 1982).

Table 3.2: Exponential growth with acceleration or deceleration

Crops	Exponential growth in Area	Acceleration/ Deceleration	Exponential growth in production	Acceleration/ Deceleration	Exponential growth in Productivity	Acceleration/ Deceleration
Wheat	1.3975	-0.0005	3.8140	-0.0010	2.2157	-0.0005
Paddy	4.9628	-0.0011	7.3599	-0.0018	2.3943	-0.0008
Cotton	-0.4618	-0.0007	1.2631	-0.0005	1.4293	0.0001
Maize	-2.7837	-0.0001	-0.8023	0.0002	2.0309	0.0003
TOS	-3.4560	-0.0009	-2.3774	-0.0008	1.6060	-0.0001
Potatoes	4.1514	-0.0001	5.1153	-0.0002	-1.2597	-0.0013
SUG	-0.6715	0.0001	0.5746	-0.0012	1.2935	-0.0003
TP	-7.0541	0.0006	-7.6703	0.0000	0.6140	0.0003
Barley	-3.8446	-0.0009	-0.6557	-0.0014	3.0264	-0.0005
Onion	6.0643	-0.0003	9.1091	-0.0004	1.1926	-0.0001
Bajra	-9.5396	-0.0004	-8.9002	-0.0012	0.6920	-0.0005

Sources: Author's Calculation,
Note: TOS=Total Oil Seeds, SUG= Sugarcane, TP = Total Pulses

3.4.3 Estimation of crop diversification index

Table 3.3 presents the degree of crops diversification over time. It implies that the trends have moved towards specialization in favour of wheat and paddy crops.

Table 3.3: Crop diversification measures in Punjab

Years	Concentration	Diversification Index	Years	Concentration	Diversification Index
	HHI	CEI		HHI	CEI
1960-61	0.30	0.59	1989-90	0.35	0.51
1961-62	0.28	0.61	1990-91	0.35	0.50
1962-63	0.27	0.61	1991-92	0.35	0.51
1963-64	0.27	0.61	1992-93	0.36	0.50
1964-65	0.22	0.69	1993-94	0.36	0.49
1965-66	0.22	0.69	1994-95	0.35	0.50
1966-67	0.22	0.70	1995-96	0.34	0.52
1967-68	0.24	0.68	1996-97	0.33	0.52
1968-69	0.27	0.66	1997-98	0.35	0.50
1969-70	0.26	0.66	1998-99	0.37	0.48
1970-71	0.27	0.65	1999-00	0.38	0.47
1971-72	0.28	0.64	2000-01	0.37	0.47
1972-73	0.28	0.64	2001-02	0.38	0.46
1973-74	0.25	0.67	2002-03	0.38	0.47
1974-75	0.24	0.69	2003-04	0.38	0.46
1975-76	0.25	0.67	2004-05	0.38	0.46
1976-77	0.27	0.65	2005-06	0.38	0.46
1977-78	0.27	0.64	2006-07	0.38	0.46
1978-79	0.28	0.62	2007-08	0.38	0.45
1979-80	0.30	0.59	2008-09	0.39	0.44
1980-81	0.29	0.60	2009-10	0.39	0.44
1981-82	0.30	0.60	2010-11	0.39	0.44
1982-83	0.33	0.56	2011-12	0.40	0.43
1983-84	0.35	0.54	2012-13	0.39	0.44
1984-85	0.33	0.55	2013-14	0.40	0.44
1985-86	0.33	0.55	2014-15	0.41	0.43
1986-87	0.34	0.53	2015-16	0.41	0.43
1987-88	0.33	0.54	2016-17	0.41	0.42
1988-89	0.33	0.53	2017-18	0.41	0.42

Sources: Directorate of Economics and Statistics
Note: HHI represents Herfindhal Index; CEI represents the Composite Entropy Index

It found that the value of CEI index has declined from 0.59 in 1960-61 to 0.42 in 2017-18, whereas HHI has increased from 0.30 to 0.41. It found that the CEI and HHI index both furnished the same results, enhancing the claim that farmers started focusing only on specialization. The results are consistent with the findings of Singh and Sidhu (2004) in which they argued that the specialization has taken place in wheat-paddy due to better return from wheat-paddy rotation, which was considered as the outcome of increase in irrigation facilitices at subsidized rates and market support for these crops.

3.4.4 Inter-temporal movement analysis of crops

Table 3.4 presents both the multi-annual and binary measures for the inter-temporal mobility of the crops in terms of area under cultivation, production, and productivity. The both RC_{at} and RC_t illustrate that there exists a downward trend as shown in Table 3.4 during the entire period. However, most interesting point is that values have come down from 1 to 0.71 for area, 1 to 0.70 for production, and 1 to 0.91 for productivity. This observation supports the findings that mobility of the crops within the overall distribution is virtually lower.

It reflects the fact that farmers have consistently devoted specific area to a few selected crops. This is mainly the result of the emergence of MSP backed agricultural policy.

Table 3.4: Inter-temporal movement of RC_t and RCat of area, production, and productivity of crops

Year	Area		Production		Productivity		Year	Area		Production		Productivity	
	RCat	RCt	RCat	RCt	RCat	RCt		RCat	RCt	RCat	RCt	RCat	RCt
1960-61	1	1	1	1	1	1	1989-90	0.927	0.920	0.868	0.845	0.968	0.957
1961-62	0.990	0.990	0.977	0.977	0.995	0.995	1990-91	0.927	0.920	0.841	0.843	0.964	0.957
1962-63	0.990	0.990	0.977	0.968	0.991	0.986	1991-92	0.877	0.918	0.759	0.838	0.968	0.957
1963-64	0.993	0.990	0.973	0.968	0.986	0.982	1992-93	0.877	0.916	0.818	0.838	0.968	0.957
1964-65	0.991	0.993	0.982	0.969	0.973	0.971	1993-94	0.905	0.916	0.818	0.838	0.973	0.958
1965-66	0.980	0.992	0.968	0.961	0.986	0.973	1994-95	0.905	0.916	0.800	0.836	0.968	0.958
1966-67	0.982	0.987	0.968	0.959	0.986	0.973	1995-96	0.868	0.914	0.814	0.836	0.968	0.958
1967-68	0.959	0.976	0.945	0.951	0.968	0.965	1996-97	0.850	0.909	0.795	0.835	0.959	0.958
1968-69	0.964	0.969	0.891	0.934	0.964	0.960	1997-98	0.864	0.907	0.773	0.834	0.959	0.958
1969-70	0.973	0.968	0.909	0.926	0.964	0.953	1998-99	0.823	0.903	0.782	0.833	0.964	0.958
1970-71	0.964	0.966	0.909	0.921	0.959	0.951	1999-00	0.827	0.900	0.777	0.833	0.964	0.958
1971-72	0.945	0.960	0.932	0.919	0.964	0.950	2000-01	0.868	0.899	0.764	0.832	0.968	0.958
1972-73	0.945	0.957	0.932	0.918	0.977	0.951	2001-02	0.827	0.896	0.777	0.833	0.927	0.954
1973-74	0.920	0.951	0.936	0.917	0.955	0.949	2002-03	0.814	0.892	0.777	0.833	0.968	0.954
1974-75	0.909	0.941	0.873	0.905	0.977	0.952	2003-04	0.827	0.890	0.777	0.834	0.968	0.955
1975-76	0.927	0.939	0.914	0.903	0.973	0.952	2004-05	0.832	0.889	0.777	0.834	0.968	0.955
1976-77	0.936	0.936	0.909	0.901	0.964	0.950	2005-06	0.814	0.887	0.691	0.830	0.968	0.956
1977-78	0.936	0.932	0.886	0.892	0.973	0.951	2006-07	0.795	0.884	0.709	0.828	0.968	0.956
1978-79	0.936	0.930	0.886	0.886	0.968	0.952	2007-08	0.795	0.881	0.709	0.826	0.968	0.957
1979-80	0.936	0.928	0.850	0.877	0.977	0.954	2008-09	0.782	0.877	0.705	0.824	0.973	0.957
1980-81	0.925	0.927	0.850	0.870	0.959	0.954	2009-10	0.786	0.874	0.705	0.823	0.982	0.958
1981-82	0.936	0.926	0.768	0.857	0.959	0.954	2010-11	0.795	0.872	0.705	0.821	0.982	0.959
1982-83	0.936	0.925	0.836	0.853	0.968	0.955	2011-12	0.782	0.870	0.705	0.820	0.982	0.958
1983-84	0.936	0.925	0.877	0.854	0.968	0.956	2012-13	0.805	0.868	0.750	0.820	0.914	0.955
1984-85	0.941	0.924	0.823	0.851	0.973	0.957	2013-14	0.795	0.867	0.709	0.820	0.914	0.951
1985-86	0.927	0.922	0.859	0.849	0.977	0.956	2014-15	0.818	0.865	0.695	0.818	0.911	0.947
1986-87	0.927	0.920	0.868	0.849	0.959	0.956	2015-16	0.777	0.862	0.695	0.817	0.911	0.943
1987-88	0.905	0.920	0.832	0.847	0.968	0.957	2016-17	0.745	0.859	0.695	0.816	0.911	0.939
1988-89	0.927	0.920	0.827	0.843	0.968	0.957	2017-18	0.714	0.854	0.709	0.816	0.911	0.936

3.4.5 Decomposition of sources of growth in agricultural output

Above analysis of area, production, and productivity of the selected crops in Punjab merely explains the growth pattern and its direction of change. This cannot give a confirmation of the effect of area and productivity on the total variation in the production of the crops. To know about this, decomposition analysis is applied here. Table 3.5 illustrates crop-wise area effect, yield effect, and interaction effect to total output change. In the case of wheat; area, yield, and interaction effects have contributed about 37.50 percent, 32.57 percent, and 29.93 percent respectively during the period 1960-61 to 1989-90. It is observed that the area and yield effects have increased continuously from 44.19 percent to 50.16 percent respectively, whereas the interaction effect has contributed only 5 percent during 1990-91 to 2017-18. The decline in interaction effect is captured by area and yield components.

Similarly, in case of paddy; area, yield, and interaction effects have contributed about 8.21 percent, 37 percent and 67.17 percent respectively from 1960-61 to 1989-90. The contributions of area and yield effects have increased to 41.92 percent and 67.17 percent, while the contribution of interaction effect has declined to about -9.08 percent during 1990-91 to 2017-18. Except wheat and paddy, other crops have shown declining trends in terms of their contributions of area effect, yield effect, and interaction effect. In terms of production, potato is an important vegetable crop produced in Punjab but the analysis shows the deceleration of area effect and yield effect under cultivation of this crop. It can be observed that the decline in diversification system is influenced by increasing contribution of area effect and yield effect of land to the production of crops, especially for the wheat and paddy.

As stated in the literature, increasing agricultural output is possible either through expanding the area under crops or enhancing the productivity of the crops or through both. Area under a crops can be increased by substituting one with another and productivity can be enhanced through the adoption of various yield enhancing technologies. However, the present outcomes show that, in case of pulses, neither the area under the crops nor the productivity has increased during the last four decades; whereas increase in cereal production was caused by an increase in both area and yield.

Table 3.5: Area, yield and interaction effect of the crops

Crops	1960-61 to 1989-90			1975-76 to 2004-05			1990-91 to 2017-18		
	Area Effect	Yield Effect	Interaction Effect	Area Effect	Yield Effect	Interaction Effect	Area Effect	Yield Effect	Interaction Effect
Wheat	37.50	32.57	29.93	49.00	47.67	03.33	44.19	50.16	05.65
Paddy	08.21	37.30	54.49	15.84	71.31	12.85	41.92	67.17	-9.08
Cotton	57.39	34.54	08.07	73.58	45.88	-19.46	45.46	41.82	12.72
Maize	19.73	68.48	11.79	28.71	72.88	-1.59	05.81	54.90	39.29
TOS	20.63	72.95	06.42	29.63	78.10	-7.73	11.42	70.20	-12.69
Potatoes	0.04	83.87	16.09	00.34	99.38	0.29	0.19	81.60	-44.83
SUG	70.12	18.88	10.99	83.72	39.42	-23.13	60.37	35.51	04.11
TP	77.07	23.31	-0.38	33.55	70.25	-3.80	13.17	64.87	21.97
Barley	03.75	47.56	48.68	8.80	92.72	-1.51	01.18	88.87	09.95
Onion	0.0006	75.78	24.22	00.03	99.92	00.05	00.01	93.35	06.65
Bajra	14.69	56.88	28.43	14.88	85.55	-0.43	00.98	97.48	01.54

Sources: Directorate of Economics and Statistics (DES)
Note: TOS=Total Oil Seeds, SUG= Sugarcane, TP = Total Pulses

It is pointed out that, continuous decline in productivity under pulses is caused by the low yield during 1960-61 to 2017-18. The farmers give less emphasis on the pulses crops because of the low availability of inputs, higher risk in production, non- availability of quality seed, low market demand, high labour needs, lack of production techniques of pulses at farm level and absence of proper care (Bhatia, 1991; Singh & Grover, 2015).

Table 3.6 presents the overall picture of each component along with its interaction effects. On the individual level, it shows that during 1960-61 to 1974-75 around 41 percent and 30 percent growth is accounted by yield and area effects respectively, whereas cropping pattern effect have contributed only a meager proportion of 0.49 percent. But this pattern has changed during 2005-06 to 2017-18, where area effect has gone down to 5.56 percent while yield and cropping pattern effects have increased to 94.97 percent and 69.22 percent respectively. Moreover, the interaction effect of area, yield and cropping pattern contribute only 3.71 percent to the total agricultural production, while the highest proportion of 12.42 percent is contributed by the combined effects of yield and cropping pattern. In brief, the results clearly indicate that major part in total production is accounted by growth in yield followed by cropping pattern.

Table 3.6: Sources of agricultural growth in Punjab

Effects	1960-61 to 1974-75	1975-76 to 1989-90	1990-91 to 2004-05	2005-06 to 2017-18
Individual				
Area Effect	29.73	15.76	4.41	5.56
Yield effect	41.18	40.01	53.57	94.97
Cropping effect	0.49	21.43	24.15	69.22
Sub total	71.40	77.20	82.13	169.75
Interaction				
Area and Cropping pattern	0.15	3.90	1.38	0.25
Area and Yield	12.31	7.28	3.07	0.34
Cropping and Yield	12.42	9.83	12.69	-70.09
Area, yield and cropping pattern	3.71	1.79	0.73	-0.25
Sub total	28.60	22.80	17.87	-69.75
Grand total	100	100	100	100

Source: Author's Calculation by using data from Directorate of Economics and Statistics

3.4.6 Determinants of crop diversification

Table 3.7 presents the factors that affect the level of crop diversification. The results found that the variables number of market per hectare, length of road per hectare, urbanization, number of tractor per hectare, and rainfall per hectare have a statistically significant and positive impact on diversification as expected, whereas the amount of fertilizer per hectare, intensity of irrigation per hectare, and cropping intensity have a negative impact on crop diversification. Since the coefficient of two variables LMARKT (00471) and LROAD (00228) are positive and statistical significant, it suggested that infrastructure aspects in Punjab have positive impact on crop diversification. But, over-dependence of the farmers on irrigation and fertilizer is negatively impacting degree of crop diversification. As the results shows the coefficient of two variables LNPK (-0.0622) and LIRRINTY (-0.0623) are negatively and statistically significant.

Table 3.7: Estimated regression coefficients of Equation (3.8)

Variables	(1)	(2)
	Composite Entropy Index	
	Pooled OLS	Fixed Effects
LMARKT	0.0199***	0.0471***
	(0.0072)	(0.0105)
LROAD	0.0237***	0.0228***
	(0.0039)	(0.0033)
LNPK	-0.0690***	-0.0622***
	(0.0063)	(0.0088)
LIRRINTY	-0.0947***	-0.0623**
	(0.0248)	(0.0259)
LUB	0.0337**	0.0341***
	(0.0139)	(0.0090)
LTRC	0.0020***	0.0024***
	(0.0007)	(0.0004)
LRAIN	0.0197***	-0.0749
	(0.0044)	(0.0456)
LCI	-0.0912**	1.1866***
	(0.0451)	(0.1738)
Constant	1.1179***	
	(0.1544)	438
		49
Observations	435	0.3902
Number of year	0.7118	0.380
R-squared	0.706	0.4398
Adjusted R-Squared	117.6	0.428
F stat	-0.0199***	64.46

Note: Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

3.5 Conclusion and Policy Implications

The objectives of this chapter were (i) to explore the trend and pattern of crop diversification in Punjab, and (ii) identify the factors those determine crop diversification. HHI and CEI have been estimated to measure the degree of crop diversification for 1960-61 to 2017-18. The findings reveal that cropping pattern has changed in Punjab state. The green revolution shifted focus of farmers towards a few crops mainly wheat-rice rotation. These crops have sowed on maximum area due to favourable conditions such as relatively higher and stable returns, low uncertainties in production and remunerative ensured price as compared to other competing crops. Even though if it look throughout the study period, state has achieved acceleration in growth in productivity of maize, cotton and total pulses but the state is still concentrated on wheat-rice pattern. This remarkable change in cropping pattern is the result of wider usage of high yielding variety seeds, electricity policy, and food procurement policy introduced during the green revolution period. More specifically, regarding key components responsible for the change in total production are area effect and yield effect. From the above analysis, it can be stated that decline in crop diversification has been influenced by the increasing contribution of the area and yield effects of land to the total production of crops, especially for the wheat and rice crops. Further, it also found the factors number of market per hactare, lengh of road per hactare, urbanization, number of tractor per hactare, and rainfall per hactare are positively related to diversification as expected. But, over-dependence of the farmers on irrigation and fertilizer are negatively impacting degree of crop diversification. As the results shows the coefficient of two variables LNPK (-0.0622) and LIRRINTY (-0.0623) are negatively and statistically significant. The policy perception for the cropping pattern is that the farmers will switch in favour of others crops such as oil seeds, pulses etc. only when they are sure of getting higher profits, less risk and backed by effective procurement policy.