International Journal of Business and Management Invention (IJBMI)
ISSN (Online): 2319-8028, ISSN (Print):2319-801X
www.ijbmi.org || Volume 12 Issue 6 || June 2023 || PP 95-106

Trend and Pattern of Crop Diversification in West Bengal During Post Liberalisation Era: An Application of Cluster Analysis

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Abstract
Crop diversification is one of the most important risk management and income enhancing strategies for farmers. It is practiced by the farmers in West Bengal as a risk mitigating strategy. The present study attempts to investigate the trend and pattern of crop diversification across districts of West Bengal during the post liberalization era. The analysis is based on secondary data. The period under study has been divided into four sub-periods, namely, Triennium Ending (TE) 1992-93, TE 2002-03, TE 2012-13 and TE 2019-20. The number of districts selected for the purpose of study are seventeen (17). The four major indices of crop diversification, namely, the Simpson's index, the Composite Entropy index, the Modified Entropy index and the Herfindahl index have been used to estimate the magnitudes of diversification for different districts of West Bengal. The average magnitude of crop diversification of the state as a whole has increased over time from Triennium Ending 1992-93 to Triennium Ending 2019-20 measured in terms of all four indices (the decreasing magnitude of Herfindahl index implies increasing crop diversification). There are seven districts above the state average in terms of their respective magnitudes of crop diversification as per the indices chosen during the first two sub periods, while in the two subsequent sub periods, the number of districts above the state average has increased to eight. Nadia, Murshidabad and Malda remained at the top of the list throughout the period under study. The magnitudes of diversification for these districts are above 0.8 irrespective of the index chosen (excepting Herfindahl index). The lowest magnitudes of crop diversification are recorded in the districts of Purulia and South 24 Parganas in terms of the four indices selected during the entire study period. The district of Purulia has registered the lowest magnitude of diversification throughout the study period, which is below 0.4, irrespective of the index chosen (excepting Herfindahl index). The Cluster analysis has been applied for grouping the districts in terms of the degrees of diversification. Here Hierarchical clustering method has been used and the districts are classified using Ward's Method under Agglomerative clustering. The results show that the districts of West Bengal and the state as a whole have exhibited higher crop diversification in new millennium compared to the nineties.

Keywords: Crop Diversification, Cluster Analysis, Composite Entropy Index, Herfindahl Index, Modified Entropy Index, Simpson's Index,

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Date of Submission: 02-06-2023 Date of Acceptance: 13-06-2023

I. Introduction:

The agriculture and allied sector continue to be pivotal to the sustainable growth and development of the Indian economy. Not only does it meet the food and nutritional requirements of 1.3 billion Indians, it contributes significantly to production, employment and demand generation through various backward and forward linkages leading to a multiplier impact on the gross domestic product of the economy. Moreover, the role of the agricultural sector in alleviating poverty and in ensuring the sustainable development of the economy is also well established. The sector is, however, currently facing a dilemma. While it has made large strides in achieving the agricultural development goals of food security, availability and accessibility, it is still being challenged by a formidable agrarian crisis in the form of 'farmers' welfare'. This situation has recently led a to fresh thinking on the developmental approach in the agricultural sector. The need for focusing on the welfare and prosperity of the farmers has gained prominence (State of Indian Agriculture 2015-16, Ministry of Agriculture & Farmers Welfare, Government of India).

Indian agriculture is predominantly a small and marginal peasant based economy with approximately 85% of the operational holdings lying below two hectares and at the same time only 44.58% of the agricultural land being cultivated by them (Agriculture Census 2010-11). Because of small operational holdings, it is indeed very difficult for the small farmers to improve their earnings only by raising the yields of the existing crops, mainly cereals. However, with the availability of modern farm inputs in recent times, farmers have a ready

option to generate higher levels of income by introducing high value crops commonly known as cash crops in their farming units. Thus, the high value crops being more labour intensive, usually provide stable employment and income to a large section of the rural households who face the severe problem of seasonal unemployment and underemployment under mono-crop economy. Therefore, diversification from low value crops to high value crops at farm level can solve many of the problems faced by small and marginal farmers.

In general, diversification is an integral part of the process of structural transformation of an economy. A deviation from agriculture towards industries and services denotes diversification (across sectors) at the macro level. But there is a lack of clarity when it comes to diversification within a sector itself, and the same holds true for agriculture sector as well. In Indian agriculture, diversification has occurred both between crops and across activities (that is, crop cultivation, livestock raising, forestry and fishing). Within the primary sector, the share of output and employment in the non-crop sectors, i.e. animal husbandry, forestry and fisheries, have been gradually increasing. Thus, significant diversification is taking place in terms of moving away from crop production to other agriculture-allied activities. Simultaneously, similar significant changes are taking place even within the crop sector which is evident from changes in cropping pattern (Singh et.al.2006).

So, to summarize, there are two kinds of diversification at farm level-- horizontal diversification and vertical diversification. Horizontal diversification refers to the cultivation of different kinds of crops, that is, minor crops, vegetables and fruits along with conventional major crops at farm level by farmers. Vertical diversification occurs when farmers adopt some other enterprises i.e. livestock rearing, poultry farming and fish farming along with growing of crops at farm level (Haque,T. 1996).

It should be mentioned here that the incidence of crop diversification was very uncommon in India before the introduction of new agricultural strategy in the mid-sixties. With the advent of new agricultural technology, particularly, water - seed- fertilizer technology, a significant change in land allocation towards some high value cash crops such as fruits and vegetables is evidenced in India, particularly by the small farmers (Joshi et. al, 2004).

Crop diversification as a concept and tool is a strategy to maximize the use of land, water and other resources and for the overall agricultural development in the country. It provides the farmers the opportunity to grow different crops on their land throughout the year. The diversification in agriculture is also practiced with an intention to avoid risk and uncertainty arising from climatic and biological vagaries. It minimizes the adverse effects of the current system of crop specialization and mono culture for better resource use, nutrient recycling, reduction of risks and uncertainty and better soil conditions.

Agricultural diversification leading to a change in cropping pattern towards high value crops is undoubtedly a major factor contributing towards agricultural development. The reasons are twofold. First, it has been observed that the impact of the green revolution in cereals gets exhausted after an 'optimum' level is reached, that is, agricultural growth becomes stagnant. Secondly, the small and the marginal farmers who dominate the agricultural scenario of most of the Indian states, including West Bengal, can generate higher farm income and employment and mitigate risks by adopting a diversified crop portfolio (Vyas, 1996).

Hence it may be argued that the small and marginal farmers, depending on a small piece of land and having no alternative sources of employment and income would try to cultivate as many crops as possible and choose high value crops such as Boro paddy, oilseeds , potato, jute, fruits & vegetables which after meeting their consumption needs, would meet their requirements for daily living. Even the medium and large farmers approach diversification for the improvement of their living standard. Thus, crop diversification in India can be viewed as the survival strategy of the farmers as well as a way towards increasing their income and employment opportunity particularly for the small and marginal ones.

During the recent decades, the process of diversification has been wide-spread due to the combined effects of water-seed- fertilizer technology as well as some infrastructural development such as market centers, roads, transport etc., in the countryside (Vyas, 1996; Bhalla and Singh, 1997).

In West Bengal, an interesting observation is that a marked diversification of cropping pattern away from food grains has occurred since economic liberalization. The share of cropped area under non-food grains increased substantially almost over the past two three decades.The percentage of acreage of oilseeds, particularly mustard, nearly doubled during 1980-2006. The area under potato also increased significantly during the same period. However, the share of cropped area under jute declined over this period, although increased in the 1990s (West Bengal Development Report, Planning commission, GOI, 2007). In West Bengal, 95.91 per cent of the operating households belong to the marginal and small category and operating about 80.71 per cent of the total land holding (Government of West Bengal, 2014). Like other states of India, the small farmers of West Bengal have given high priority to high value crops like summer paddy, mustard, potato, jute and vegetables (De, 2000). Agriculture in West Bengal has is,therefore, diversifying gradually towards high value crops. West Bengal is one of the leading producers of fruits and vegetables contributing nearly 16 per cent to the country's total production in 2005-06 (Government of India, 2010). The value of total fruits and vegetables produced in the state increased by more than twice during 1990-91 to 2005-06.

II. Objective:

The specific objectives of this paper are:

i) To analyze the trend of horizontal crop diversification during 1990-91 to 2019-20

ii) To examine the pattern of crop diversification across districts of West Bengal during 1990-91 to 2019-20 using the Cluster analysis

III. The Study Area

The study focuses on 17major districts of West Bengal during 1990-91 to 2019-20. Due to non-availability of disaggregated data for both South and North Dinajpur from 1990-91 to 1995-96, the study has considered Dinajpur as a single district in the name of West Dinajpur. The district of Midnapore has been administratively divided after 2002. However, the agricultural division was done in the 1990s. So East Midnapore and West Midnapore have been considered separately. Alipurduar has emerged as an independent district in 2014, so it has been considered as a part of Jalpaiguri- its mother district. Similarly, Jhargram, East Bardhaman and West Bardhaman have been given recognition of independent districts in 2017. Hence Jhargram has been considered as a part of West Midnapore and East and West Bardhaman have been taken together as Bardhaman. Kalimpong has been considered as a part of its original district Darjeeling from where it was separated in 2017.

IV. Selection of Crop under Study

Rice is cultivated in all the seventeen districts of West Bengal. The two most important varieties are Aman and Boro. The third variety of rice namely Aus is also cultivated in all the districts but the area under Aus is significantly low. Wheat is cultivated in all the districts. The cereal crops namely, Aman, Boro and Wheat have been considered separately in the study. Other cereals cultivated in the state are Maize, Barley, Jowar, Bajra, Ragi, Small Millets. However, excepting Maize, the other cereal crops are not cultivated uniformly in all the districts. This is why the study categorizes all these crops including Aus in a single group, namely, 'other cereals'. Pulses are cultivated in all the districts of West Bengal but the varieties differ. The most important varieties of pulses include Masoor, Mung, Urad, Matar, Gram, Tur etc. Hence, total Pulses has been selected as a single category. Oilseeds are cultivated in all the district of West Bengal. The most important crops in this category are Rapeseed and Mustard, cultivated in all the districts. Other varieties of Oilseeds produced in West Bengal are Sesamum, Groundnut, Linseed, Sunflower, Safflower, not cultivated uniformly over the districts. Therefore, 'Oilseeds' is taken as a single category comprising all types of oilseeds cultivated in the state. Jute is selected as a crop for the purpose of study. Jute is cultivated in all the districts of West Bengal, however the area under cultivation significantly differs. Potato is one of the major crops in the state which is considered in the analysis. It is cultivated in all the districts. Organized data for vegetable cultivation is available for West Bengal since the year 2000-01. Hence vegetable as a separate category has been selected after 2000-01. The major producers of different crops in terms of area allocation are shown in the following table.

Table1: Major Crop Producing Districts in terms of Area Allocation

Crops	Major Producing Districts
Aman	West Midnapore, Bardhaman, West Dinajpur, Birbhum, South 24 Parganas, Purulia
Boro	West Midnapore, Bardhaman, East Midnapore, Nadia, Murshidabad
Wheat	Malda, Murshidabad, Jalpaiguri, West Dinajpur, Birbhum
Other Cereals	West Dinajpur, Nadia, West Midnapore, Malda, Murshidabad, Jalpaiguri, Darjeeling
Pulses	Nadia, Malda, Murshidabad, West Dinajpur, Birbhum, South 24 Parganas
Oilseeds	Murshidabad, North 24 Parganas, Hooghly, West Dinajpur, West Midnapore, Bardhaman, Nadia
Jute	Nadia, Murshidabad, North 24 Parganas, Coochbihar, Jalpaiguri, West Dinajpur
Potato	Hooghly, Coochbihar, Jalpaiguri, Bardhaman, Bankura, West Midnapore, Nadia
Vegetables	Malda, Murshidabad, North 24 Parganas, Hooghly, Coochbihar, Jalpaiguri, West Dinajpur, West Midnapore, Bardhaman

Author's Calculation

Data Source and Methodology

The secondary data at district level and state level for West Bengal have been collected from different issues of "District Statistical Hand Book". The "State Domestic Product and District Domestic Product of West Bengal" published by Bureau of Applied Economics & Statistics, Department of Statistics & Programme Implementation, Government of West Bengal, have also been used as secondary data source. Data have also been taken from various issues of "Estimates of Area & Production of Principal crops in West Bengal" Evaluation Wing, Directorate of Agriculture, Government of West Bengal.

Research Methodology

A. Measuring Crop Diversification

There are quite a few methods that explain either concentration (specialization) or diversification of crop in a given time and space by a single indicator. Important ones include:

(i) **Entropy Index (EI)**

EI = $-\sum_i^N P_i \, log_{10} P_i$

Where P_i stands for the proportion of area under the ith crop. The index increases with an increase in diversification and the upper value of the index can exceed 'one' when the total number of crops is higher than the value of the logarithmic base i.e.10. The value of index approaches zero when there is complete concentration. When the number of crops is less than the value of logarithmic base, the value of the index varies between zero and one.

(ii) **Modified Entropy Index (MEI)**

MEI = $-\sum_i^N P_i \, log_N P_i$

MEI incorporates the number of crops as the base of the logarithm. The lower and upper values of MEI are 0 (total concentration) and 1 (perfect diversification).

(iii) **Composite Entropy Index (CEI)**

The formula for CEI is

CEI = $-\sum_{i=1}^{N}(Pi \, log_N \, Pi \,)$* {1- (1/N)}

The CEI has two components, namely the distribution (P_i) and the number of crops (N). The value of the Composite Entropy Index increases with the decrease in concentration and rises with the number of crops [Chand Ramesh,1996; Pandey VK and Sharma KC,1996]. The value of CEI ranges from zero to one.

(iv) **Herfindahl Index**.

Mathematically, the HI index is defined as

HI = $\sum_{i=1}^{N} {p_i}^2$

Where N = Total number of crops; Pi = Proportion of acreage under the i^{th} crop to the total cropped area. This index was first used to measure the regional concentration of industries [Theil, 1967]. The value of HI is bounded by 0 (perfect diversification) and 1 (complete specialization).

The other important measure of diversification is Simpson's Index (SID)

(v) **Simpson's Index (SID)**

SID = $1 - \sum_{i=1}^{N} Pi^2$

Pi is the proportionate area (or value) of the i^{th} crop activity in the gross cropped area (or the total value of output), while N is the number of crops.

The Simpson's index takes into account both richness (the number of crop species present in a particular area) and evenness (the relative abundance of different crop species) of crops present in a particular area. As crop richness and evenness increase, diversity increases. The Simpson's index ranges between 0 and 1. If there exists complete specialization, the index moves towards zero and away from zero implies diversification. The most widely used method for measuring diversity in recent times is Simpson's index as it is easy to compute and interpret [Joshi PK et.al., 2004;]. Considering our objective of assessing the extent of diversity in crop activities, all the above-mentioned measures will be used in our study.

B. Spearman's Rank Correlation

A rank correlation coefficient measures the degree of similarity between two rankings, and can be used to assess the significance of the relation between them. Spearman's rank correlation measures the strength and direction of association between two ranked variables. It basically gives the measure of monotonicity of the relation between two variables, i.e. how well the relationship between two variables could be represented using a monotonic function.

The formula for Spearman's rank coefficient is:

$$\boldsymbol{\rho} = 1 - \frac{6\sum d^2}{n(n^2 - 1)}$$

$\boldsymbol{\rho}$ = Spearman's rank correlation coefficient

d_i = Difference between the two ranks of each observation

n = Number of observations

The Spearman Rank Correlation can take a value from +1 to -1

C. Cluster Analysis

Clustering is the task of grouping similar objects in such a way that the objects in the same group have properties more similar to each other compared to those in other groups.

In cluster analysis there are two types of clusters- non-hierarchical and hierarchical. In this study, hierarchical clustering has been used. Hierarchical clustering has further been divided into agglomerative and divisive clusters. In the present study, the districts are clustered by agglomerative clustering using Ward's method based on the values of different crop diversification indices of different districts.

Ward's method is also marked as a method of minimizing the increases of errors of sum squares. It is based on optimizing the homogeneity of clusters according to the criteria of minimizing the increase of errors of sum squares of deviation points from centroid. This is the reason why this method is different from other methods of hierarchical clustering, which are based on optimization of the distance between clusters [J. Bacher, A. Poge and K. Wenzig, 2010].

The loss of information is determined at each level of clustering, which is expressed as the increase of total sum of aberrance square of each cluster point from the average ESS value. Then it comes to a connection of clusters where there is a minimal increase in the errors of sum of squares [J. Han and M. Kamber,2006].

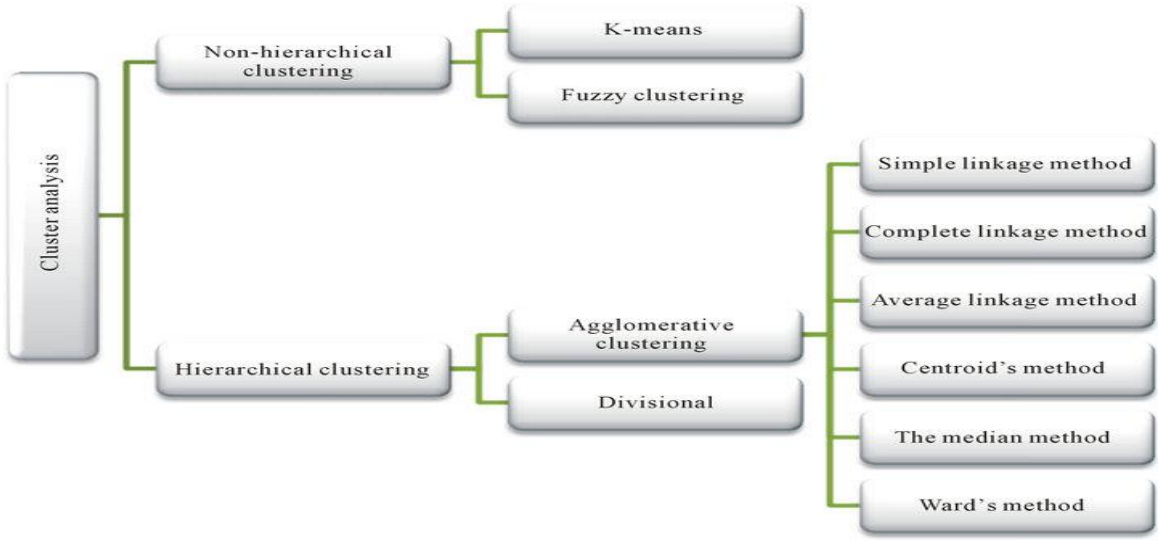
The accruement of ESS (Errors of Sum of Squares) function is calculated according to [J. Han and M. Kamber,2006]:

$$\Delta ESS\left(A_i, A_j\right) = \frac{1}{2} d_{ES}\left(A_i, A_j\right),\ A_i, A_j \in o,$$

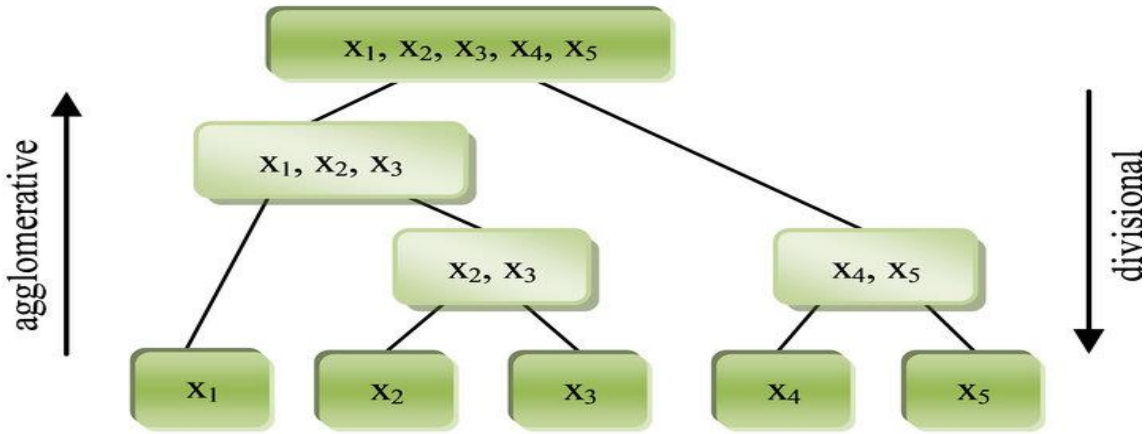
Where

$$i, j = 1, 2, \cdots, n$$

i) Classification of Cluster Analysis



ii) Principle of Cluster Analysis



V. Results and Discussion:

The data have been classified into four sub-periods, that is, triennium ending (TE) 1992-93, TE 2002-03, TE 2012-13, TE 2019-20. The crop diversification indices chosen for the purpose of study are Simpson's Index (SI), Herfindahl Index (HI), Modified Entropy Index (MEI), Composite Entropy Index (CEI).

Part A. Spatiotemporal analysis of Crop Diversification in West Bengal using different Crop Diversification Indices

A.1 Crop Diversification during triennium ending 1992-93

From table 2 it can be seen that during TE 1992-93, the district level magnitude of diversification has been measured using all the chosen four indices Nadia recorded the highest level of crop diversification in terms of the four indices. SI for Nadia is 0.839 whereas HI is 0.161. The MEI for Nadia is as high as 0.967 and the CEI is 0.829.

The average magnitude of crop diversification for the state of West Bengal during TE 1992-93 is 0.654 and 0.346 in terms of SI and HI respectively. As per MEI it is 0.695 and it is 0.617 according to CEI. The districts which lie above the state average in terms of the magnitude of crop diversification measured by SI and HI are Murshidabad, Malda, North 24 Parganas, Coochbihar, Hooghly and Darjeeling. These districts come after Nadia in terms of decreasing order of magnitude of crop diversification. The districts in terms of Modified Entropy Index lying above the state average and coming after Nadia are Malda, Murshidabad, Darjeeling, Hooghly, North 24 Parganas and Coochbihar. According to Composite Entropy Index the districts with magnitudes above state average lying below Nadia in decreasing order are Malda, Murshidabad, North 24 Parganas, Hooghly, Coochbihar and Darjeeling.

Though in terms of different measures of crop diversification the relative position of the seven districts lying above the state average has altered but the districts continued to remain the same. This is also true for the districts lying below the state average.

Table :2 Magnitudes of Crop Diversification of Different Districts in West Bengal during TE **1992-93**

Districts	Si	HI	Districts	MEI	Districts	CEI
Nadia	0.839	0.161	Nadia	0.967	Nadia	0.829
Murshidabad	0.806	0.194	Malda	0.910	Malda	0.780
Malda	0.795	0.205	Murshidabad	0.872	Murshidabad	0.763
North 24 Parganas	0.707	0.293	Darjeeling	0.768	North 24 Parganas	0.647
Coochbihar	0.707	0.293	Hooghly	0.754	Hooglhy	0.646
Hooghly	0.701	0.299	North 24 Parganas	0.740	Coochbihar	0.641
Darjeeling	0.690	0.310	Coochbihar	0.732	Darjeeling	0.640
West Bengal	0.654	0.346	West Bengal	0.695	West Bengal	0.617
West Dinajpur	0.628	0.372	West Dinajpur	0.684	West Dinajpur	0.598
Jalpaiguri	0.605	0.395	Bardhaman	0.627	Bardhaman	0.538
Bardhaman	0.581	0.419	Jalpaiguri	0.606	Jalpaiguri	0.530
Howrah	0.563	0.437	Howrah	0.572	Paschim Midnapore	0.486
Purba Midnapore	0.533	0.467	Purba Midnapore	0.556	Howrah	0.477
Paschim Midnapore	0.524	0.476	Paschim Midnapore	0.555	Purba Midnapore	0.477
Bankura	0.486	0.514	Birbhum	0.523	Bankura	0.454
Birbhum	0.451	0.549	Bankura	0.518	Birbhum	0.448
Purulia	0.284	0.716	Purulia	0.314	Purulia	0.275
South24 Parganas	0.263	0.737	South24 Parganas	0.274	South24 Parganas	0.240

Source: Author's calculation

The lowest magnitudes of crop diversification are recorded in the district of Purulia and South 24 Parganas in terms of all four indices during TE 1992-93. The Simpson's, Herfindahl, Modified Entropy Index and Composite Entropy Index for Purulia are 0.284, 0.716, 0.314 and 0.275 respectively where the magnitudes of these four indices for South 24 Parganas are even lower at 0.263,0.737, 0.274 and 0.240 respectively.

The districts lying below the state average in terms of magnitudes of diversification but above Purulia and South 24 Parganas are West Dinajpur, Jalpaiguri, Bardhaman, Howrah, East(Purba) Midnapore, West(Paschim) Midnapore, Bankura and Birbhum as per both Simpson's and Herfindahl's Indices. In terms of Modified Entropy Index these districts are West Dinajpur, Bardhaman, Jalpaiguri, Howrah, East(Purba) Midnapore, West(Paschim) Midnapore, Birbhum and Bankura. The Composite Entropy Index registers the districts below state average as West Dinajpur, Bardhaman, Jalpaiguri, West(Paschim) Midnapore, Howrah, East (Purba) Midnapore, Bankura and Birbhum in descending order of magnitude.

A.2 Crop Diversification at Triennium Ending 2002-03

The results for the sub period TE 2002-03 are presented in table 3. During this sub period, the district which recorded the highest magnitude of crop diversification in terms of all four indices (i.e., Simpson's Index, Herfindahl Index, Modified Entropy Index and Composite Entropy Index) is Nadia once again. The magnitudes of crop diversification for Nadia are 0.856 (SI), 0.144(HI), 0.964(MEI) and 0.843(CEI). These figures have recorded a marginal increase compare to TE 1992-93 excepting the MEI which shows a little decline from 0.967 to 0.964.

The magnitude of state average has increased in TE 2002-03 in comparison with TE 1992-93 measured in terms of all four indices. The figures for the state average during TE 2002-03 are 0.751, 0.249, 0.773 and 0.695 measured of Simpson's Index, Herfindahl Index, Modified Entropy Index and Composite Entropy Index respectively.

The states lying above state average in terms of their respective magnitudes of crop diversification below Nadia are Murshidabad, Malda, North 24 Parganas, Darjeeling, Jalpaiguri, Hooghly (Simpson's Index, Herfindahl's Index), Murshidabad, Malda, Darjeeling, North 24 Parganas, Jalpaiguri, Hooghly (Modified Entropy Index) and Murshidabad, Malda, North 24 Parganas, Jalpaiguri, Darjeeling and Hooghly (Composite Entropy Index).

Table : 3 Magnitudes of Crop Diversification of Different Districts in West Bengal during TE 2002-03

Districts	SI	HI	Districts	MEI	Districts	CEI
Nadia	0.856	0.144	Nadia	0.964	Nadia	0.843
Murshidabad	0.847	0.153	Murshidabad	0.917	Murshidabad	0.816
Malda	0.818	0.182	Malda	0.908	Malda	0.795
North 24 Parganas	0.798	0.202	Darjeeling	0.835	North 24 Parganas	0.739
Darjeeling	0.798	0.202	North 24 Parganas	0.831	Jalpaiguri	0.736
Jalpaiguri	0.795	0.205	Jalpaiguri	0.818	Darjeeling	0.730
Hooghly	0.780	0.220	Hooghly	0.812	Hooghly	0.711
West Bengal	0.751	0.249	West Bengal	0.773	West Bengal	0.695
West Dinajpur	0.741	0.259	West Dinajpur	0.765	West Dinajpur	0.680
Coochbihar	0.717	0.283	Coochbihar	0.753	Coochbihar	0.669
Howrah	0.682	0.318	Howrah	0.715	Howrah	0.613
Bardhaman	0.679	0.321	Bardhaman	0.694	Bardhaman	0.607
Paschim Midnapore	0.646	0.354	Birbhum	0.677	Paschim Midnapore	0.596
Birbhum	0.627	0.373	Paschim Midnapore	0.672	Birbhum	0.592
Purba Midnapore	0.625	0.375	Purba Midnapore	0.625	Purba Midnapore	0.546
Bankura	0.577	0.423	Bankura	0.590	Bankura	0.525
South24 Parganas	0.522	0.478	South24 Parganas	0.575	South24 Parganas	0.444
Purulia	0.389	0.611	Purulia	0.391	Purulia	0.348

Source: Author's calculation

The districts that lie at the bottom of the table with lowest magnitudes of crop diversification are South 24 Parganas and Purulia in terms of all the four indices.

A.3 Crop Diversification in Triennium Ending 2012-13

The district level magnitudes of crop diversification have been measured using all the four selected indices during TE 2012-13. Nadia recorded the highest level of crop diversification in terms of the indices chosen. SI for Nadia is 0.859 whereas HI is 0.141. The MEI for Nadia is as high as 0.966 and the CEI is 0.846.

The average magnitudes of crop diversification for the state of West Bengal during TE 2012-13 are 0.753 and 0.247 in terms of SI and HI respectively. As per MEI it is 0.0.774 and it is 0.696 according to CEI. The magnitudes of crop diversification have recorded marginal increase during TE 2012-13 compared to previous two triennium ending 1992-93 and 2002-03.

The districts lying above the state average in term of their magnitudes of crop diversification measured by SI and HI are Murshidabad, North 24 Parganas, Malda, Jalpaiguri, Darjeeling, Hooghly and West Dinajpur. These are the districts coming after Nadia in decreasing order of magnitudes of crop diversification. The districts in terms of Modified Entropy Index that are above the state average after Nadia are Murshidabad,

Table: 4 Magnitudes of Crop Diversification of Different Districts in West Bengal during TE 2012-13

Districts	SI	HI	Districts	MEI	Districts	CEI
Nadia	0.859	0.141	Nadia	0.966	Nadia	0.846
Murshidabad	0.843	0.157	Murshidabad	0.902	Murshidabad	0.802
North 24 Parganas	0.810	0.190	Malda	0.885	Malda	0.774
Malda	0.803	0.197	North 24 Parganas	0.839	Jalpaiguri	0.749
Jalpaiguri	0.802	0.198	Darjeeling	0.835	North 24 Parganas	0.746
Darjeeling	0.798	0.202	Jalpaiguri	0.832	Darjeeling	0.731
Hooghly	0.775	0.225	Hooghly	0.802	West Dinajpur	0.706
West Dinajpur	0.756	0.244	West Dinajpur	0.794	Hooghly	0.702
West Bengal	0.753	0.247	West Bengal	0.774	West Bengal	0.696
Coochbihar	0.729	0.271	Coochbihar	0.756	Coochbihar	0.670
Howrah	0.681	0.319	Howrah	0.719	Howrah	0.617
Paschim Midnapore	0.675	0.325	Birbhum	0.677	Paschim Midnapore	0.593
Bardhaman	0.649	0.351	Paschim Midnapore	0.668	Birbhum	0.592
Purba Midnapore	0.629	0.371	Bardhaman	0.657	Bardhaman	0.575
Birbhum	0.628	0.372	Purba Midnapore	0.629	Purba Midnapore	0.551
Bankura	0.600	0.400	Bankura	0.598	Bankura	0.531
South24 Parganas	0.575	0.425	South24 Parganas	0.562	South24 Parganas	0.499
Purulia	0.346	0.654	Purulia	0.339	Purulia	0.301

Source: Author's calculation

Malda,North 24 Parganas, Darjeeling, Jalpaiguri, Hooghly and West Dinajpur. According to Composite Entropy Index the districts with magnitudes above state average lying below Nadia in decreasing order are Murshidabad, Malda, Jalpaiguri, North 24 Parganas, Darjeeling, West Dinajpur and Hooghly.

There are eight districts above the state average in terms their magnitudes of crop diversification as per the indices chosen. Of these districts, six have altered their relative positions while Nadia and Murshidabad have held their positions fixed.

The lowest magnitudes of crop diversification are recorded in the districts of Purulia and South 24 Parganas in terms of the four indices selected during TE 2012-13. The Simpson's Index, Herfindahl's Index, Modified Entropy Index and Composite Entropy Index for Purulia are 0.346, 0.654, 0.339 and 0.301 respectively. The district of South 24 Parganas has recorded a slightly higher magnitude of crop diversification than Purulia with values being 0.575, 0.425, 0.562 and 0.499 respectively.

The districts lying below the state average in terms of magnitudes of diversification above Purulia and South 24 Parganas are Coochbihar, Howrah, West(Paschim) Midnapore, Bardhaman, East(Purba) Midnapore, Birbhum and Bankura in terms of Simpson's and Herfindahl's Indices. However according to Modified Entropy Index these districts are Coochbihar, Howrah, Birbhum, West(Paschim) Midnapore, Bardhaman,

East(Purba) Midnapore and Bankura. The Composite Entropy Index register the districts below state average and above Purulia and South 24 Parganas as Coochbihar, Howrah, West(Paschim) Midnapore, Birbhum, Bardhaman, East(Purba) Midnapore and Bankura. The magnitudes of crop diversification using different indices for the sub period TE 2012-13 are presented in table 4.

A.4 Crop Diversification during Triennium Ending 2019-20

The district which recorded the highest magnitude of crop diversification in terms of all four indices (i.e., Simpson's Index, Herfindahl's Index, Modified Entropy Index and Composite Entropy Index) is Nadia once again during TE 2019-20 which can be seen from table 5. The magnitudes of crop diversification for Nadia are 0.851 (SI), 0.149(HI), 0.931(MEI) and 0.815(CEI). These figures have recorded a marginal decrease compared to TE 2012-13.

The magnitude of state average has increased in TE 2019-20 in comparison with TE 2012-13 measured in terms of all four indices. The figures for the state average during TE 2019-20 are 0.766, 0.234, 0.793 and 0.714 measured by Simpson's Index, Herfindahl's Index, Modified Entropy Index and Composite Entropy Index respectively.

The states lying above state average in terms of their respective magnitudes of crop diversification below Nadia are Murshidabad, Jalpaiguri, Malda, North 24 Parganas, West Dinajpur, Coochbihar, Hooghly (Simpson's Index, Herfindahl's Index), Murshidabad, Malda, Jalpaiguri, West Dinajpur, North 24 Parganas,Coochbihar, Hooghly (Modified Entropy Index and Composite Entropy Index).

Table : 5 Magnitudes of Crop Diversification of Different Districts in West Bengal during TE 2019-20

Districts	SI	HI	Districts	MEI	Districts	CEI
Nadia	0.851	0.149	Nadia	0.931	Nadia	0.815
Murshidabad	0.842	0.158	Murshidabad	0.895	Murshidabad	0.796
Jalpaiguri	0.826	0.174	Malda	0.894	Malda	0.783
Malda	0.812	0.188	Jalpaiguri	0.861	Jalpaiguri	0.775
North 24 Parganas	0.811	0.189	West Dinajpur	0.839	West Dinajpur	0.746
West Dinajpur	0.788	0.212	North 24 Parganas	0.836	North 24 Parganas	0.744
Coochbihar	0.776	0.224	Coochbihar	0.802	Coochbihar	0.712
Hooghly	0.772	0.228	Hooghly	0.801	Hooghly	0.715
West Bengal	0.766	0.234	West Bengal	0.793	West Bengal	0.714
Darjeeling	0.759	0.241	Darjeeling	0.779	Darjeeling	0.682
Paschim Midnapore	0.701	0.299	Howrah	0.722	Bardhaman	0.631
Bardhaman	0.684	0.316	Bardhaman	0.721	Birbhum	0.628
Howrah	0.675	0.325	Birbhum	0.718	Howrah	0.619
Birbhum	0.664	0.336	Paschim Midnapore	0.695	Paschim Midnapore	0.618
Purba Midnapore	0.645	0.355	Bankura	0.628	Bankura	0.558
South24 Parganas	0.630	0.370	Purba Midnapore	0.625	Purba Midnapore	0.547
Bankura	0.621	0.379	South24 Parganas	0.592	South24 Parganas	0.526
Purulia	0.382	0.618	Purulia	0.380	Purulia	0.337

Source: Author's calculation

The district that lies at the bottom of the table with lowest magnitudes of crop diversification is Purulia in terms of all the four indices.

The districts lying below the state average but appearing above Purulia in terms of their respective magnitudes of crop diversification are Darjeeling, Bardhaman, Howrah, East(Purba) Midnapore, West(Paschim) Midnapore, Bankura, Birbhum and South 24 Parganas as per all the indices (Simpson's Index, Herfindahl's Index, Modified Entropy Index and Composite Entropy Index).

Relative Position of Districts Over Time

The study so far has discussed the magnitudes of crop diversification in absolute terms for different districts of West Bengal under four different sub periods under consideration. Now it is attempted to see whether there has

been any change in the relative position of the districts in terms of the crop diversification magnitudes between subsequent sub periods and also between the first and the last sub periods selected. The Spearman's rank correlation method is used here for the sake of analysis. The rank correlation coefficients between different sub periods have been calculated on the basis of Simpson's Index (SI) and Composite Entropy Index (CEI). The outcome is presented in table 6.

Table 6: Rank Correlation coefficients between sub periods during TE 1992-93 to TE 2019-20

Time	**Based on SI**	**Based on CEI**
Between TE 1992-93 & TE 2002-03	0.946*	0.929*
Between TE 2002-03 & TE 2012-13	0.931*	0.917*
Between TE 2012-13 & TE 2019-20	0.963*	0.953*
Between TE 1992-93 & TE 2019-20	0.971*	0.953*

Source: Author's calculation
*** Significant at 1% level**

The magnitude of the coefficient based on SI is 0.946 while it is 0.929 on the basis of CEI between TE 1992-93 and TE 2002-03. It is observed that between TE 2002-03 and TE 2012-13 the coefficients are 0.931 and 0.917 based on SI and CEI respectively. The magnitudes of the coefficients are found to be 0.963 and 0.953 using SI and CEI respectively between TE 2012-13 and TE 2019-20. Finally, the rank correlation coefficients between the first and the last sub period, i.e., between TE 1992-93 and TE 2019-20 are 0.971 and 0.953 based on SI and CEI respectively. It is interesting to note that the magnitudes of the rank correlation coefficients slightly fall short of (+)1. This implies that there has been a very little change in the rank of the districts in the crop diversification ladder during the period under study. The change in the relative position of the districts over time has separately been discussed in the next sub-section using cluster analysis.

Part B. District level analysis of Pattern of Crop Diversification in West Bengal using cluster analysis

In the standard literature a certain magnitude of crop diversification is randomly selected and set as a benchmark to determine the hierarchical position of the districts. The districts are categorized in terms of magnitudes crop diversification in relation to this set value. However, the cluster analysis categorizes the districts in a more scientific way in terms of their respective magnitudes of crop diversification.

On the basis of the magnitudes of selected crop diversification indices, an attempt has been made to cluster the districts to find out the trend and pattern of crop diversification during different sub periods under study**.** There are five hierarchical clusters in this study which are presented in Table 7 based on dendrogram (Annexure Figure 1 to Annexure Figure 4). Nadia, Murshidabad and Malda always belong to cluster I, that is, the excellent category in terms of diversification while Purulia remains in cluster V, i.e., the lowest category, throughout the period under study. The district of South 24 Parganas, was in cluster V, i.e., the lowest category in sub-period I but shifted to the cluster IV (moderate group) in the subsequent three sub-periods. This implies that South 24 Parganas has slowly moved up over time.

The district of West Dinajpur was in cluster III in sub-period I but interestingly moved up to the cluster II during the two subsequent sub periods and further shifted to cluster I in sub period IV. The district of Jalpaiguri has shifted from cluster III in sub period I to cluster II in Sub period II and finally to cluster I in sub periods III and IV.

Table: 7 Categorization of Districts according to Diversification during 1990-91 to 2019-20

	Diversification	TE 1992-93	TE 2002-03	TE 2012-13	TE 2019-20
Cluster	Value	Name of the Districts	Name of the Districts	Name of the Districts	Name of the Districts
Cluster I	Excellent	Nadia, Murshidabad, Malda	Nadia, Murshidabad, Malda	Nadia, Murshidabad, North 24 Parganas, Jalpaiguri, Malda,	Nadia, Murshidabad, Malda, Jalpaiguri , West Dinajpur, North24 Pgs 24
Cluster II	Very High	North 24 Parganas, Hooghly, Darjeeling, Coochbihar,	North 24 Parganas, Jalpaiguri, Hooghly, Darjeeling ,Coochbihar, West Dinajpur	Coochbihar, Hooghly, Darjeeling, West Dinajpur,	Coochbihar, Hooghly, Darjeeling,
Cluster III	Moderately High	Jalpaiguri, Bardhaman , West Dinajpur	Bardhaman , Howrah, West Midnapore, Birbhum	Bardhaman , Birbhum, Howrah, West Midnapore	Bardhaman , Birbhum, Howrah, West Midnapore

Cluster IV	Moderate	Birbhum , West Midnapore, Howrah, Bankura, East Midnapore,	East Midnapore, Bankura, South 24 Parganas	Bankura, ,East Midnapore, South 24 Parganas	Bankura, East Midnapore, South 24 Parganas
Cluster V	Very Low	South 24 Parganas, Purulia	Purulia	Purulia	Purulia

Source: Authors' calculation

It is interesting to note that though the districts of West Dinajpur and Jalpaiguri have both moved up in the crop diversification ladder from sub period I to Sub period IV but the pace of movement of Jalpaiguri is much faster than that of West Dinajpur. Similarly, North 24 Parganas was in cluster II during first two sub periods but shifted to cluster I during the next two sub periods.

Darjeeling, Coochbihar and Hooghly remain in cluster II (Very high category of diversification) throughout the study period and Bardhaman has continued to remain in cluster III. Bankura and East Midnapore have all along remained in cluster IV in all the study periods. Howrah and West Midnapore started with moderate diversification (i.e. cluster IV) in sub period I but shifted to moderately high category (i.e., cluster III) during the next three sub periods. Bankura and East Midnapore have always remained in cluster IV.

VI. Conclusion:

Crop diversification is practiced by Indian farmers as a strategy towards risk management and enhancing farmers' income. Since Indian agriculture is still largely dominated by small and marginal farmers who have to depend on the mercy of the climate, crop diversification has been considered as a viable alternative towards reducing the risk of crop failure. In fact, crop diversification has become a popular agricultural strategy in India once the effects of Green Revolution became stagnant. The present study has focused on the trend and pattern of crop diversification across different districts of West Bengal in the post liberalization era. For the sake of convenience of analysis, the period has been divided into four sub-periods with an interval of ten years for the first three sub periods and Triennium Ending 2019-20 chosen as the last sub period due to non- availability of secondary data .Crop diversification indices for the 17 districts of West Bengal have been calculated using five different measures of diversification. By using the Ward's method under Hierarchical clustering, the districts have been grouped into five clusters explaining the trend and pattern of crop diversification during the study period.

The districts which continue to remain at the highest cluster in terms of diversification are Nadia, Murshidabad and Malda whereas Purulia exhibited the lowest level of diversification or in other words the highest crop concentration throughout the entire study period. The districts of Jalpaiguri and West Dinajpur performed very well by moving from the moderately diversified cluster to excellently diversified cluster over time. But Jalpaiguri diversified at a faster pace in comparison with West Dinajpur.

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ANNEXURE:

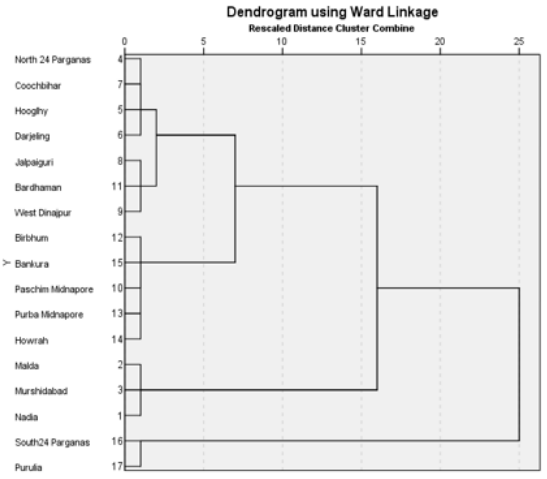

Fig1

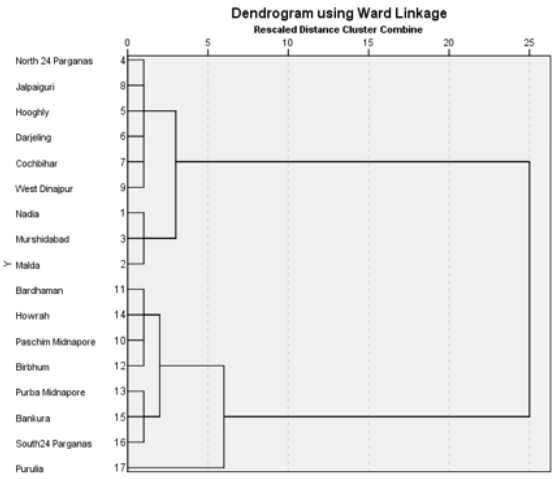

Fig2

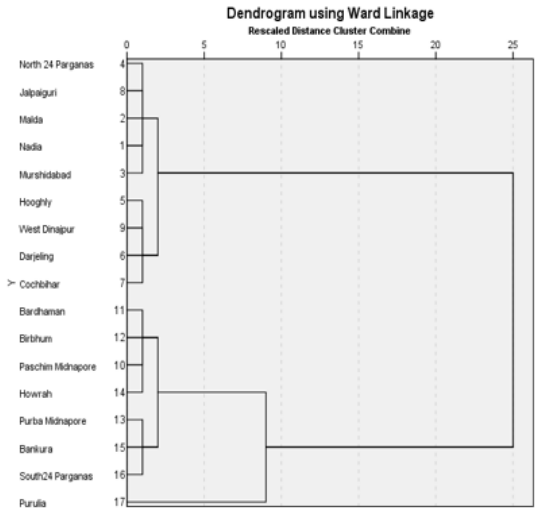

Fig3

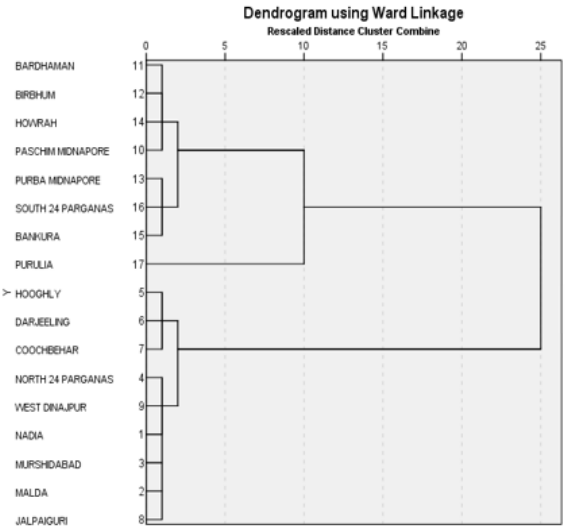

Fig4