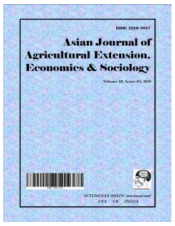

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# Factors Influencing Crop Diversification in Different Agro - Climatic Zones of West Bengal: An Application of Principal Component Analysis

**Debasis Mithiya[1*], Kumarjit Mandal[2] and Simanti Bandyopadhyay[3]**

*[1]Department of Business Administration, International School of Hospitality Management, Kolkata, India.*
*[2]Department of Economics, University of Calcutta, Kolkata, India.*
*[3]Department of Economics, Victoria Institution (College), University of Calcutta, Kolkata, India.*

***Authors' contributions***

*This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

The state of West Bengal has been divided into three agro-climatic regions that can further be stratified into six agro-climatic sub-regions, with specific climatic features. Each climatic sub-region (or zone) has different possibilities of crop production determined by its agro-climatic features along with demand and supply related factors. Farmers have been observed to practice crop diversification in each sub-zone. Crop diversification is an effective method of eliminating uncertainty involved in agriculture and raising farmers' income. The present study intends to analyze the pattern of crop diversification and the factors influencing it in different agro-climatic zones of West Bengal. The Simpson's index has been used to estimate diversification. The results show that all the zones (except Eastern Plateau & Hilly zone), as well as the state of West Bengal as a whole, have witnessed -rising crop diversification since the new millennium compared to the nineties. The Principal Component Regression (PCR) has been used to identify the factors that

**Corresponding author: E-mail: drdebasis.mithiya@gmail.com;*

influence the shift in cropping pattern in each agro-climatic zone. Eleven variables have been included in the Principal Component Analysis (PCA). The first four Eigenvalues capture maximum variability and the corresponding four components have been selected for PCR. Both the supply-side and the demand-side variables have been taken into consideration for analyzing PCA. The demand-side factors like the size of the urban population, per capita income and supply-side variables such as the proportion of small landholders, area under High Yielding Varieties (HYV) and density of markets play a significant role in determining crop diversification in all the agro climatic zones (except 'Eastern Plateau and Hilly zone').

*Keywords: Crop diversification; principal component analysis; Simpson's index; agro-climatic zone; high-value crops.*

**JEL Classification:** Q10, C38, C43, Q57.

## 1. INTRODUCTION

Agriculture plays a vital role in India's economy. Over 58 percent of the rural households depend on agriculture as their principal means of livelihood. Agriculture, along with its allied sectors like fishery and forestry, is one of the largest contributors to the GDP [1]. As per the 2$^{nd}$ advanced estimates by the Central Statistical Organisation (CSO), the share of agriculture and allied sectors is expected to be 17.32 percent of the Gross Value Added during 2016-17 at current prices [2]. However, agriculture is a precarious occupation as it deals with uncertain issues like weather and market situations [3]. This insecurity can culminate into inaccuracy about farm income assessments that farmers make in certain seasons. Hence farm income unpredictability is a serious problem that the agricultural sector has to deal with. Agricultural diversification is often used to mitigate such risks. Diversification in agriculture means the diversion of a sizeable acreage from the existing crop system to some alternative crop or cropping system or farm enterprises [4]. In India, diversification has occurred both across and within the crop or farm enterprises such as livestock, forestry and fishery sectors [5]. Shifting cropping pattern is a strategy of shifting from less-profitable to more profitable crops or from traditionally grown less remunerative crops to more remunerative crops [6].

Crop diversification refers to changing of cropping system, increasing exports and competitiveness in both domestic and international markets, protecting the environment and making conditions favourable for combining enterprises resultant with the shift in cropping pattern [7]. Diversification has also been defined as a change in product choice and input use decisions based on market forces and the principles of profit maximization [8]. Therefore, crop diversification implies the shift from subsistence farming to commercial farming or from low-value food crops to high-value food or non-food crops [9,10]. The level of diversification largely depends on the agro-climatic and socio-economic conditions and technological development in a region [11]. Crop diversification also takes place due to governmental policies and importance placed on some specific crops during a given period of time. For instance, the Technology Mission on Oilseeds (TMO) was created to boost oilseeds production as a national need and to reduce excessive dependence on oilseeds import. Market infrastructure development and certain other price-related support also induce a shift in cropping pattern. Higher profitability and the stability in production are other factors that lead to crop diversification. Crop diversification and cultivation of a large number of crops are practiced in rain-fed lands to reduce the risk of crop failure due to less rain or drought. Crop substitution and shift are also taking place in the areas with distinct soil problems.

A new approach to agricultural planning - the Agro Climatic Regional Planning (ACRP) was put into action in 1988. This holistic approach digresses from the sectoral approach of planning, which was in practice till 2015. It explicitly recognizes the local resource endowments and constraints of the agro-climatically homogeneous regions, quite often cutting across the states. The ACRP can be considered as a bridge between the resource base and decentralized planning, which aims at providing a scientific support to planning for attainment of sustainability having due consideration of basic resources and the local needs. The project was initiated by regionalizing the country into 15 regions/zones and later into

73 sub-regions/zones and subsequently demarcation of sub-zones within a state using district as the lowest unit of analysis. The principles used for this sub-regionalization were those which relate intrinsically with the character of the agricultural economy like soil, climate, rainfall, etc. [12].

The physiographic setting of West Bengal comes under three agro-climatic regions. The three broad regions are Eastern Himalayan Region (Zone II), Lower Gangetic Plain Region (Zone III) and Eastern Plateau & Hilly Region (Zone VIII). Three broad regions are further stratified into six agro-climatic sub-regions [13].

Zone II: Eastern Himalayan Region

- Hills sub-region: Covering Darjeeling district.
- Terai sub-region: Covering Jalpaiguri and Coochbehar district.

Zone III: Lower Gangetic Plain Region

- Old Alluvium sub-region: Comprising West Dinajpur and Malda districts.
- New Alluvium sub-region: Covering Murshidabad, Nadia, Hooghly, Burdwan and North 24 Parganas.
- Coastal-Saline sub-region: Covering South 24 Parganas, Howrah and East Midnapore.
- Red-Laterite sub-region: Covering Birbhum, Bankura, and West Midnapore districts.

Zone VIII: Eastern Plateau & Hilly Region:

- The region covers Purulia district.

*To relate crop diversification with agro-climatic zones, the present study focuses on the nature of agricultural diversification in different agro-climatic zones of West Bengal. Our study also analyses the factors which affect crop diversification in different agro-climatic zones.*

The specific objectives of this paper are:

1. To analyze the pattern of crop diversification in different agro-climatic zones of West Bengal.
2. To analyze the factors that influence crop diversification across different agro-climatic zones of West Bengal.

## 2. TYPE AND SOURCES OF DATA

The secondary data at district level and state level for West Bengal have been collected from various issues of "District Statistical Hand Book" and "Estimates of 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. Data have also been collected from different volumes of "Estimates of Area & Production of Principal crops in West Bengal" Evaluation Wing, Directorate of Agriculture, Government of West Bengal. The study covers the period between 1990-91 and 2013-14.

## 3. RESEARCH METHODOLOGY

### 3.1 Measuring Crop Diversification

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

(i) Ogive Index (OI) that is computed to get an idea about the extent of crop diversification. OI is given by the formula:

$$\text{OI} = N\ \sum_1^N \{(p_i - (\tfrac{1}{N})\}^2$$

Where, $Pi$ = Proportion of acreage under $i^{th}$ crop to total cropped area, *N* = Total number of crops cultivated in the region. OI takes larger values with increasing diversification and its value decreases with rising specialization. It was first used by Tress [14] to measure the industrial diversity.

Two other indices have been considered as inverse measures of concentration. These are Entropy Index (EI) and Modified Entropy Index (MEI). These two measures are widely used by agricultural economists for analyzing diversification of agriculture [15].

(ii) The formula for computing Entropy Index (EI) is

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

Where Pi stands for the proportion of area under 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.

(iii) In order to get a more accurate measure, Modified Entropy Index (MEI) is used, which is defined as

$$\text{MEI} = \sum_{i=1}^{N}(Pi\ log_N\ Pi\ )$$

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).

The other measure is Composite Entropy Index (CEI)

(iv) The formula for CEI is

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

The CEI has two components, namely the distribution (Pi) 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 [16,17]. The value of CEI ranges from zero to one.

Another important index of crop diversification is Herfindahl Index.

(v) Mathematically, the HI index is defined as

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

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 [18]. 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).

(vi) The formula for computing Simpson's Index (SID) is given by

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

$Pi$ 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 [19]. Considering our objective of assessing the extent of diversity in crop activities and the application of the above measures in the various studies, Simpson's Index has been considered, given its applicability.

*To calculate the extent of crop diversification, the study considers the area under cultivation of nine different agricultural crops such as aman paddy, boro paddy, wheat, pulses, other cereals, oilseeds, potato, jute, vegetables, and tea from the following different agro-climatic zones of West Bengal for the period 1990-91 to 2013-14.*

### 3.2 Econometric Model to Assess the Factors Influencing the Crop Diversification

In order to assess the factors influencing the shift in cropping pattern in different agro-climatic zones of West Bengal, a regression approach has been used. The variables that have been considered as the explanatory variables (independent variables) are broadly grouped into (i) technology related, (ii) infrastructure related, (iii) resources-information related, (iv) demand related (v) climate related and (vi) relative earning related variables. To capture their effect, a few proxy variables have been used in the model. For technology, the proxy variables are the proportionate area under high yielding varieties of food grain crops (percent), fertilizer use (kg per ha), net irrigated area (ha). For infrastructure, these variables are market density (number of markets per 1000 ha of the gross cropped area), and road- length (square km per 1,000 ha of the gross cropped area). The relative price of high-value crops with respect to rice is the proxy for farmers' earning. The proportion of small landholders in total holdings is used as a proxy for the available resources. Rural literacy (percent) has been used as a proxy for information related variable. On the demand side, variables such as the size of urban population (percent) and per capita income (rupees per person) are used in the model. Annual rainfall (mm) has been used to define the climate related variable in the model. Simpson's index has been used for measuring the extent of crop diversification and the index values have been considered as the dependent variables.

*The principal component analysis has been carried out for grouping the variables, wherein the principal components have been used as explanatory variables [20]. In the next stage, the regression analysis has been carried out by regressing Simpson's index on different components of crop diversification. The significance of the variables can be identified by the value (>0.3) of the factor loadings in each principal component which are found to be significant in principal component regression.*

#### 3.2.1 Principle component regression model (PCR)

Model using PCR method begins with PCA, primarily to reduce the dimensions of the variables or to overcome the problem of multicollinearity [21]. The number of Principal Components used in the PCR model has been selected based on the cumulative proportion of the total variability in the range of 65 percent to 95 percent. In this context, the principal components are considered as regressor variables and the dependent variable is Simpson's index of crop diversification (SID). Dummy variables in the PCR model help to overcome the problem of error of heterogeneity. The PCR model with dummy variables is a better model than the PCR model without dummy variables [22,23].

The Simpson's index has been specified as a function of the following Principal Components. The model for principal component regression is given by Equation (1):

$$SID = \beta_0 + \beta_1\, PC1 + \beta_2\, PC2 + \beta_3\, PC3 + \beta_4\, PC4 + \beta_5 Dummy + €_i \ldots\ldots \quad (1)$$

PC = Principal Components, Dummy = time dummy

$\beta_i$ = all Co-efficient,

Where, $i$ = 0,1, 2, 3, 4, 5

## 4. RESULTS AND DISCUSSION

### 4.1 Inter-Regional Crop Diversification

Table 1 explains the result of Simpson's index and indicates the extent of the shift in cropping pattern across different agro-climatic sub-regions of West Bengal. In the analysis of inter-regional crop diversification, it is observed that the magnitude of crop diversification index increases over time in all the sub-regions. The summary of the table shows 'Eastern Plateau and Hilly' region has no crop diversification (magnitude of SI remains more or less the same), Coastal-Saline and Red-Laterite sub-zone show a moderate crop diversification and the remaining sub-zones experienced high level of crop diversification. Among these sub-regions, New Alluvium sub-region is the highest diversified region followed by Hills sub-region, Terai sub-region, and Old Alluvium sub-region. The Coastal-Saline sub-zone and Red-Laterite sub-zone show a moderate level of crop diversification throughout the period under analysis.

As evident from the above Table, if we consider the state of West Bengal as a whole, it shows a moderately high level of crop diversification. Old Alluvium, New Alluvium, Hills, and Terai sub-regions are more diversified than the state as a whole. However, the Red-Laterite sub-zone, Coastal -Saline sub-zone, and 'Eastern Plateau & Hilly' regions are less diversified than West Bengal as a whole.

*Agro-climatic zone-wise values of crop diversification, using other indices like 'Herfindahl index, Entropy index, and Ogive index' also show a similar pattern for all the chosen sub-periods (Annexure 1).*

Table 2 shows that New Alluvium and Old Alluvium sub-regions have always belonged to a highly diversified category. The 'Eastern Plateau and Hilly' region has always remained in the low diversified group. The Hills sub-region and the Terai sub-region remained in the moderately diversified group in the first sub-period which subsequently moved into the highly diversified group in the next sub-period. Similarly, Red-Laterite sub-region and Coastal-Saline sub-region have moved from low to moderately diversified group.

**Table 1. Crop diversification index of different agro climatic zone in west bengal during 1990-91 to 2013-14**

| Agro climatic zone | TE 1990-93 | TE 2000-2003 | TE 2013-2004 |
|---|---|---|---|
| | Simpson's index | Simpson's index | Simpson's index |
| New Alluvium Sub-Region | 0.764 | 0.823 | 0.801 |
| Hills Sub-Region | 0.689 | 0.798 | 0.798 |
| Terai Sub-Region | 0.667 | 0.769 | 0.780 |
| Old Alluvium Sub-Region | 0.710 | 0.773 | 0.776 |
| Red-Laterite Sub-Region | 0.463 | 0.594 | 0.617 |
| Coastal-Saline Sub-Region | 0.452 | 0.599 | 0.623 |
| Eastern Plateau & Hilly Region | 0.284 | 0.389 | 0.346 |
| West Bengal | 0.655 | 0.761 | 0.766 |

*Source: Authors' calculation*

**Table 2. Categorization of different agro climatic zone according to crop diversification**

| Level of diversification | Agro climatic zone | | |
|---|---|---|---|
| | TE 1990-93 | TE 2002-03 | TE 2012-13 |
| Highly Diversified (>0.7) | New Alluvium Sub-Region, Old Alluvium Sub-Region | New Alluvium Sub-Region, Hill Sub-Region, Terai Sub- Region, Old Alluvium Sub-Region | New Alluvium Sub Region, Hill Sub-Region, Terai Sub-Region, Old Alluvium Sub-Region |
| Moderately Diversified (≥ 0.5 ≤ 0.7) | Hill Sub-Region, Terai Sub- Region | Red and Laterite Sub-Region, Coastal Saline Sub-Region | Red and Laterite Sub-Region, Coastal Saline Sub-Region |
| Low Diversified (<0.5) | Red and Laterite Sub-Region, Coastal Saline Sub-Region, Eastern Plateau and Hilly Region | Eastern Plateau and Hilly Region | Eastern Plateau and Hilly Region |

*Source: Table 1 and Annexure 1*

### 4.2 Factors Affecting Crop Diversification

Altogether, eleven variables have been included in the principal component analysis (PCA) of which the first four Eigenvalues capture maximum variability and the corresponding four components are selected for further analysis. The Principal Component Regression (PCR) has been carried out for the period 1990-91 to 2013-14 [4]. *The rotated component matrix of independent variables with different factor loadings for all the agro-climatic zones under consideration has been provided in Annexure II which is calculated by using SPSS software.* The factor loadings represent the weights assigned to each of the variables in the linear combination corresponding to each Eigenvalue. The values of factor loadings obtained for each principal component indicate that all the variables are significant.

#### 4.2.1 New alluvium sub-region

Table 3 depicts that the first Eigenvalue (6.068) captures maximum variability (55.162 percent) and the second Eigenvalue (1.489) indicates the second highest variability (13.537 percent). The third and the fourth components capture 13.069 percent and 11.675 percent variability respectively and so on, with eleven components altogether. The first four Eigenvalues capture majority of the variability (93.444 percent).

The first component in Table 1 of Annexure II for New Alluvium sub-region shows that weight assigned for the first variable (size of urban population) is 0.899 and that for the second variable (fertilizer consumption) is 0.896 and so on.

In Table 4, the principal regression component results explain that the intercepts, the first principal component, the second principal component and the fourth principal component are positive and statistically significant. The third principal component is not statistically significant. The first principal component has a positive influence on crop diversification based on the value of rotated first principal component factor loading. Similarly, second, third and fourth

**Table 3. Eigenvalue and percentage of variance of new alluvium sub-region during 1990-91 to 2013-14**

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|
| Eigen value | 6.068 | 1.489 | 1.438 | 1.284 |
| Variance (%) | 55.162 | 13.537 | 13.069 | 11.675 |
| Cumulative (%) | 55.162 | 68.699 | 81.769 | 93.444 |

**Table 4. Principal component regression statistics of new alluvium sub-region during 1990-91 to 2013-14**

| | Constant | PC 1 | PC 2 | PC 3 | PC 4 | Dummy |
|---|---|---|---|---|---|---|
| Coefficient | 0.800* | 0.021* | 0.012* | 0.004 | 0.006* | -0.003 |
| t-value | 170.316 | 5.466 | 5.106 | 1.555 | 2.839 | -0.388 |
| F Statistic | 26.51 (5,18) | | | | | |
| R- Square | 0.880 | | | | | |
| Adjusted R Square | 0.847 | | | | | |
| S E of the Estimate | 0.009762 | | | | | |
| D-W Statistic | 1.983 | | | | | |

components influence crop diversification based on the values of rotated second, third and fourth principal component factor loadings respectively.

The computed $R^2$ and the adjusted $R^2$ in this model are 0.880 and 0.847 respectively. The result indicates that around 88 percent of the variation in the dependent variable is explained by these four principal components. The calculated F value is 26.517 and DW statistic is 1.986. The results of this regression have been chosen at 5 percent level of significance.

It can be said that the variables in first rotated component factor are of the urban population, per capita income, fertilizer consumption, area under HYV, rural literacy rate, a proportion of small landholders and the number of regulated markets have positive effects on crop diversification but a length of road has a negative effect. The variable in the second factor loadings is irrigation which is positively influencing the shift in cropping pattern. Relative price is the variable of the fourth rotated component which influences crop diversification positively. The rainfall has no significant effect on crop diversification. As seen from the above table, the time dummy has no effect on crop diversification in this agro-climatic sub-region.

#### 4.2.2 Hills sub-region

Table 5 depicts that the first Eigenvalue (4.261) captures maximum variability (38.740 percent) and the second Eigenvalue (2.577) indicates the second highest variability (23.424 percent). The third (1.545) and the fourth (1.139) Eigenvalues capture 14.044 percent and 10.352 percent variability respectively and so on. The first four Eigenvalues capture maximum variability (86.560 percent). The first component in Table 2 of Annexure II depicts that the weight assigned for the first variable (number of small landholders) is 0.967 and for the second variable (rural literacy) is 0.936 and so on.

The principal component regression results of Hills sub-region presented in Table 6 explain that the intercepts and the first principal component are positive and statistically significant. The second and the fourth principal components are negative and statistically significant. The first principal component has a positive influence on crop diversification based on the value of rotated first principal component factor loading. The second and the fourth principal components have a negative influence on crop diversification based on the value of rotated second and fourth principal component factor loadings. The third component has no significant effects on crop diversification.

The computed $R^2$ and the adjusted $R^2$ in this model are 0.902 and 0.874 respectively. The result indicates that around 90 percent of the variations in the dependent variable is explained by these four principal components. The calculated F value is 33.009 and DW statistic is 1.478. The level of significance of regression results is 5 percent.

**Table 5. Eigenvalue and percentage of variance of hill sub-region during 1990-91 to 2013-14**

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|
| Eigen value | 4.261 | 2.577 | 1.545 | 1.139 |
| Variance (%) | 38.740 | 23.424 | 14.044 | 10.352 |
| Cumulative (%) | 38.740 | 62.164 | 76.208 | 86.560 |

**Table 6. Principal component regression statistics of hills sub-region during 1990-91 to 2013-14**

| | Constant | PC1 | PC 2 | PC 3 | PC 4 | Dummy |
|---|---|---|---|---|---|---|
| Coefficient | 0.754* | 0.053* | -0.021* | -0.008 | -0.012* | -0.001 |
| t-value | 80.040 | 6.724 | -3.905 | -1.827 | -2.470 | -0.074 |
| F Statistic | 33.009(5,18) | | | | | |
| R- Square | 0.902 | | | | | |
| Adjusted R Square | 0.874 | | | | | |
| S E of the Estimate | 0.021716 | | | | | |
| D-W Statistic | 1.478 | | | | | |

Therefore, it can be concluded that variables in first rotated component factor are demand related variables (size of urban population, per capita income), resource–information related variables (proportion of small landholders, rural literacy rate) and relative earning related variable have a significantly positive influence on crop diversification. The second and the fourth principal components have a negative and statistically significant effect on crop diversification. The variables in the second and the fourth factor loadings are technology related (irrigation, fertilizer consumption) and climate-related (rainfall) and both of the variables influenced crop diversification negatively. From both the first and the second coefficients of PCR and rotated component factor loadings of Hills sub-region, it can be said that infrastructure related variables (market density, road length) have a negative impact on crop diversification. The third component is based on the value of the area under HYV which is statistically insignificant. The time dummy has no impact on changing cropping pattern.

#### 4.2.3 Terai sub-region

Table 7 depicts that the first four Eigenvalues capture maximum variability (94.605 percent). The first Eigenvalue (4.972) captures 45.198 percent variability which is the maximum. The second Eigenvalue (3.031) indicates the second highest variability (27.554 percent) whereas the third (1.327) and the fourth (1.139) Eigenvalues capture 14.044 percent and 10.352 percent variability respectively. The first component in Table 3 of Annexure II depicts that the weight assigned for the first variable (market density) is (-) 0.906 and for the second variable (road length) is (-)0.888 and so on.

The PCR results of Terai sub-region presented in Table 8 explain that the intercepts and all principal components are statistically significant. The first three components are positive but the fourth one is negative. The first three principal components have a positive influence on crop diversification based on the values of the first three rotated component factor loadings. The fourth principal component is based on the value of the fourth rotated component factor loading.

The calculated $R^2$ and the adjusted $R^2$ in this model are 0.947 and 0.932 respectively. The result indicates that around 94 percent of the variations in the dependent variable is explained by these four principal components. The estimated F value is 63.872 and DW statistic is 2.360. The results of this regression have been chosen at 5 percent level of significance.

Hence, from the first, the second, and the third rotated component factors, the technology related variables (area under HYV, irrigation, fertilizer consumption), relative earning related variable (relative price), resource information related variable (proportion of small landholders) and demand related variables (size of urban population, per capita income) have positively influenced crop diversification while from the first factor loadings, infrastructure related variables (market density and road length) have impacted it negatively. The fourth principal component is based on rainfall. The result shows that the

**Table 7. Eigenvalue and percentage of variance of terai sub-region during 1990-91 to 2013-14**

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|
| Eigenvalue | 4.972 | 3.031 | 1.327 | 1.077 |
| Variance (%) | 45.198 | 27.554 | 12.061 | 9.792 |
| Cumulative (%) | 45.198 | 72.752 | 84.812 | 94.605 |

**Table 8. Principal component regression statistics of terai sub-region during 1990-91 to 2013-14**

| | Constant | PC1 | PC 2 | PC 3 | PC 4 | Dummy |
|---|---|---|---|---|---|---|
| Coefficient | 0.723* | 0.046* | 0.016* | 0.009* | -0.007* | 0.013 |
| t-value | 104.354 | 8.570 | 4.006 | 2.562 | -2.214 | 1.079 |
| F Statistic | 63.872(5,18) | | | | | |
| R- Square | 0.947 | | | | | |
| Adjusted R Square | 0.932 | | | | | |
| S E of the Estimate | 0.015163 | | | | | |
| D-W Statistic | 2.360 | | | | | |

climate-related variable (rainfall) has a negative impact on crop diversification. The dummy has no effect.

#### 4.2.4 Old alluvium sub-region

The first four Eigenvalues of Old Alluvium sub-region are 3.977, 3.741, 1.290 and 1.035 and they capture the maximum variability of 36.150 percent, 34.012 percent, 11.725 percent and 9.410 percent respectively which have been presented in Table 9. The first four Eigenvalues together capture maximum variability (91.298 percent).

The PCR results of the Old Alluvium sub-region presented in Table 10 explain that the intercepts and the first three principal components are positive and statistically significant. But the fourth principal component is negative and also statistically significant. The first three principal components have a positive influence on crop diversification based on the values of the first, second and the third rotated principal component factor loadings respectively and the fourth principal component is based on the value of the fourth rotated principal component factor loading. The rotated component factor loadings of Old Alluvium sub-region are presented in Table 4 of Annexure II.

The $R^2$ in this model is 0.844 and the adjusted $R^2$ is 0.801. The value of $R^2$ indicates that around 84 percent of the variations in the

**Table 9. Eigenvalue and percentage of variance of old alluvium sub-region during 1990-91 to 2013-14**

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|
| Eigen value | 3.977 | 3.741 | 1.290 | 1.035 |
| Variance (%) | 36.150 | 34.012 | 11.725 | 9.410 |
| Cumulative (%) | 36.150 | 70.162 | 81.888 | 91.298 |

**Table 10. Principal component regression statistics of old alluvium sub-region during 1990-91 to 2013-14**

| | Constant | PC1 | PC 2 | PC 3 | PC 4 | Dummy |
|---|---|---|---|---|---|---|
| Coefficient | 0.743* | 0.020* | 0.017* | 0.008* | -0.008* | 0.013 |
| t-value | 86.502 | 3.750 | 2.575 | 1.941 | -2.158 | 0.812 |
| F Statistic | 19.518 (5,18) | | | | | |
| R- Square | 0.844 | | | | | |
| Adjusted R Square | 0.801 | | | | | |
| S E of the Estimate | 0.016589 | | | | | |
| D-W Statistic | 1.984 | | | | | |

dependent variable is explained by these four principal components. The F statistic and DW statistic are 19.518 and 1.984 respectively. The regression results are at 5 percent level of significance.

The results suggest that the variables in the first, the second, and the third rotated factors are the area under HYV, irrigation, fertilizer consumption, number of small landholders, rural literacy rate, size of urban population, per capita income and relative price have positive effects on crop diversification but the length of road has a negative effect. The number of regulated markets is the variable in the fourth rotated component and the road length is the variable in the first rotated component factor and they are negatively influencing the shift in cropping pattern. The rainfall is the variable in second rotated component which influenced crop diversification negatively. The time dummy is statistically insignificant.

#### 4.2.5 Coastal saline sub-region

Table 11 represents that in Coastal-Saline sub-zone the first four Eigenvalues capture maximum variability (81.972 percent). The first Eigenvalue (4.942) captures maximum variability which is 44.927 percent while the second Eigenvalue (1.913) indicates the second highest variability (17.395 percent). The third (1.146) and the fourth (1.015) Eigenvalues show 10.419 percent and 9.231 percent variability respectively and so on.

Table 12 explains the PCR results of Coastal-Saline sub-zone. The intercepts and all principal components are statistically significant. The first and the second components are positive, but the third and the fourth components are negative. The first two principal components have a positive influence on crop diversification based on the values of the first and the second rotated component factor loadings. The effects of the third and the fourth principal components are negative on crop diversification based on the values of the third and the fourth rotated component factor loadings. The rotated component factor loadings of Coastal-Saline sub-region are presented in Table 5 of Annexure II.

The computed $R^2$ and the adjusted $R^2$ in this model are 0.928 and 0.908 respectively. The result indicates that around 93 percent of the variations in the dependent variable is explained by these four principal components. The value of F statistic is 46.250 and DW statistic is 1.507.

The level of significance of regression results is 5 percent.

Therefore, the variables in the first and the second rotated component factors are demand related variables (size of urban population, per capita income), resource-information related variable (proportion of small landholder), relative earning related variable (relative price), technology related variables (irrigation, fertilizer consumption) have positive influence on crop diversification whereas infrastructure related variable (road length) has affected it negatively. The effects of the third and the fourth principal components are negative on crop diversification. This implies that rainfall, number of markets and area under HYV which are variables of third and fourth factor loadings have negatively influenced crop diversification. The time dummy has no effect on crop diversification.

**Table 11. Eigenvalue and percentage of variance of coastal-saline sub-region during 1990-91 to 2013-14**

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|
| Eigen value | 4.942 | 1.913 | 1.146 | 1.015 |
| Variance (%) | 44.927 | 17.395 | 10.419 | 9.231 |
| Cumulative (%) | 44.927 | 62.322 | 72.741 | 81.972 |

**Table 12. Principal component regression statistics of coastal-saline sub-region during 1990-91 to 2013-14**

| | Constant | PC1 | PC 2 | PC 3 | PC 4 | Dummy |
|---|---|---|---|---|---|---|
| Coefficient | 0.542* | 0.042* | 0.037* | -0.012* | -0.012* | 0.026 |
| t-value | 47.557 | 4.040 | 7.568 | -2.638 | -2.654 | 1.223 |
| F Statistic | 46.250 (5,18) | | | | | |
| R- Square | 0.928 | | | | | |
| Adjusted R Square | 0.908 | | | | | |
| S E of the Estimate | 0.021907 | | | | | |
| D-W Statistic | 1.507 | | | | | |

### 4.2.6 Red- laterite sub-region

Table 13 depicts the Eigenvalues and percentage of variance of the Red-Laterite sub-region. The first Eigenvalue (4.470) captures maximum variability (40.640 percent). The second (2.051), third (1.709) and fourth (1.219) Eigenvalues capture 18.645 percent, 15.538 percent, and 11.079 percent variability respectively and so on to end up with eleven Eigenvalues. The first four Eigenvalues capture maximum variability (85.901 percent). The First component in Table 6 of Annexure II depicts that the weight assigned to the first variable (per capita income) is 0.958. For the second variable (rural literacy) the weight is 0.903 and so on.

The PCR result of the Red-Laterite sub-region presented in Table 14 indicates that the intercept, the first, the second and the third principal components are positive and statistically significant. The fourth principal component is statistically insignificant. The significant principal components have a positive influence on crop diversification based on the values of the first, second and the third rotated principal component factor loadings.

The calculated $R^2$ and the adjusted $R^2$ in this model are 0.922 and 0.900 respectively. The results indicate that around 92 percent of the variations in the dependent variable are explained by these four principal components. The calculated F value and DW statistic are 42.339 and 2.289 respectively. The regression results are significant at 5 percent level.

Therefore it can be concluded that the variables in the first, the second, and the third rotated principal components are demand related variables (size of urban population, per capita income), resource–information related variables (proportion of small landholders, rural literacy rate), technology related variables (area under HYV, fertilizer), infrastructure related variable (number of markets) and relative earning related variable have significant positive influence on crop diversification. Irrigation and road length play a negative role on crop diversification in red-laterite sub-region. The rainfall has no impact on crop diversification in this sub-region. The time dummy also has no effect on crop diversification.

### 4.2.7 Eastern plateau and hilly region

The first four Eigenvalues of ‘Eastern Plateau & Hilly’ zone are 5.280, 1.888, 1.614 and 1.112 capturing the variability of 47.996 percent, 17.163 percent, 14.672 percent, 10.106 percent respectively as presented in Table 15. The first four Eigenvalues together capture maximum variability (89.937 percent).

The results of principal component regression analysis for ‘Eastern Plateau & Hilly’ zone presented in Table 16 explain that the intercepts and time dummy have positive and statistically significant impact. But all the principal components are statistically insignificant. The

**Table 13. Eigenvalue and percentage of variance of red - laterite sub-region during 1990-91 to 2013-14**

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|
| Eigen value | 4.470 | 2.051 | 1.709 | 1.219 |
| Variance (%) | 40.640 | 18.645 | 15.538 | 11.079 |
| Cumulative (%) | 40.640 | 59.284 | 74.822 | 85.901 |

**Table 14. Principal component regression statistics of red - laterite sub-region during 1990-91 to 2013-14**

| | Constant | PC1 | PC 2 | PC 3 | PC 4 | Dummy |
|---|---|---|---|---|---|---|
| Coefficient | 0.575* | 0.043* | 0.009* | 0.038* | 0.003 | 0.020 |
| t-value | 58.948 | 5.265 | 1.908 | 7.204 | 0.699 | 1.169 |
| F-statistic | 42.339(5,18) | | | | | |
| R- Square | 0.922 | | | | | |
| Adjusted R Square | 0.900 | | | | | |
| S E of the Estimate | 0.021965 | | | | | |
| D-W Statistic | 2.289 | | | | | |

**Table 15. Eigenvalue and percentage of variance of eastern plateau & hilly region during 1990-91 to 2013-14**

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|
| Eigen value | 5.280 | 1.888 | 1.614 | 1.112 |
| Variance (%) | 47.996 | 17.163 | 14.672 | 10.106 |
| Cumulative (%) | 47.996 | 65.159 | 79.831 | 89.937 |

**Table 16. Principal component regression statistics of eastern plateau & hilly region during 1990-91 to 2013-14**

| | Constant | PC1 | PC 2 | PC 3 | PC 4 | Dummy |
|---|---|---|---|---|---|---|
| Coefficient | 0.272* | -0.012 | 0.017 | 0.015 | -0.017 | 0.082* |
| t-value | 14.081 | -0.716 | 1.879 | 1.670 | -1.730 | 2.418 |
| F Statistic | 5.490(5,18) | | | | | |
| R- Square | 0.604 | | | | | |
| Adjusted R Square | 0.494 | | | | | |
| S E of the Estimate | 0.044187 | | | | | |
| D-W Statistic | 1.574 | | | | | |

principal components are based on rotated component factor loadings of 'Eastern Plateau & Hilly' zone and are presented in Table 7 of Annexure II.

The $R^2$ and the adjusted $R^2$ calculated in this model are 0.604 and 0.494 respectively. The results point out that around 60 percent of the variations in the dependent variable is explained by these four principal components. The F value is 5.490 and DW statistic is 1.574. The results of this regression have been chosen at 5 percent level of significance.

Hence it can be concluded that none of the variables has influenced crop diversification in 'Eastern Plateau & Hilly' zone. Only time dummy has significant impact on crop diversification of this region.

## 5. CONCLUSION

Crop diversification is a strategy to maximize utilization of land, water, and other resources and for the overall agricultural development. It provides the farmers with viable options to grow different crops under different agro-climatic conditions to avoid risk and uncertainty due to climatic and biological vagaries. Indian agriculture has been diversifying during the last two decades toward high-value crops. The pace has accelerated during the decade of the 1990s. Both the supply and the demand side factors have influenced these changes. The agriculture in West Bengal has kept pace with the development at the national level. With the growth of technology, infrastructure, resource-information, relative earning and changes in consumption pattern, West Bengal's agriculture has undergone a major shift in the recent past, moving away from cereal to non-cereal crop cultivation, more specifically towards vegetables. The study shows that the state as a whole along with the major agro-climatic zones (except Eastern Plateau & Hilly region) have higher crop diversification since the beginning of the new millennium compared to the nineties. The New Alluvium sub-region shows the highest level of diversification followed by Hills sub-region, Terai sub-region, and Old Alluvium sub-region respectively. The Coastal-Saline and the Red-Laterite zone indicate comparatively low level of diversification. The 'Eastern Plateau and Hilly' zone has no diversification. The principal component regression analysis shows that there are certain variables which strongly influence agricultural diversification in a particular zone. The government needs to focus on those factors for the overall development of agriculture. A large number of crops are not cultivated in certain zones even though climatic conditions are suitable for the growth of such crops there. Hence planning for crop cultivation in different agro-climatic zones must be done more judiciously. The government policy needs to act as a catalyst for crop diversification by providing greater investments in R&D, development of roads, markets etc. In meeting the challenges emerging from globalization, agricultural sector needs to reap the advantages of crop diversification with corresponding support given by market institutions, quality infrastructure etc. The concerns for food security and risk arising out of fluctuating international markets must be taken care of in order to smooth out the process of diversification.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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## Annexure: I

**Other Indices of crop diversification of different agro-climatic zone in West Bengal during 1990-91 to 2013-14**

| Agro climatic zone | 1990-93 TE | | | 2000-2003 TE | | | 2013-2014 TE | | |
|---|---|---|---|---|---|---|---|---|---|
| | HI | OI | EI | HI | OI | EI | HI | OI | EI |
| New Alluvium Sub-Region | 0.236 | 0.891 | 0.701 | 0.177 | 0.592 | 0.787 | 0.199 | 0.793 | 0.747 |
| Hills Sub- Region | 0.310 | 0.862 | 0.597 | 0.202 | 0.617 | 0.755 | 0.202 | 0.618 | 0.756 |
| Terai Sub- Region | 0.333 | 1.662 | 0.619 | 0.231 | 1.313 | 0.800 | 0.220 | 2.998 | 0.814 |
| Old Alluvium Sub-Region | 0.290 | 1.323 | 0.697 | 0.227 | 1.039 | 0.774 | 0.224 | 1.018 | 0.783 |
| Red and Laterite Sub-Region | 0.537 | 3.300 | 0.414 | 0.406 | 2.653 | 0.540 | 0.383 | 2.443 | 0.540 |
| Costal Saline Sub-Region | 0.548 | 3.422 | 0.399 | 0.401 | 2.608 | 0.546 | 0.377 | 2.390 | 0.568 |
| Eastern Plateau& Hilly Zone | 0.716 | 4.785 | 0.284 | 0.611 | 4.501 | 0.372 | 0.654 | 4.886 | 0.323 |
| West Bengal | 0.345 | 2.046 | 0.640 | 0.239 | 1.490 | 0.742 | 0.232 | 1.469 | 0.742 |

*Source: Various issues of District Statistical Hand Books, Bureau of Applied Economics and Statistics & Different Issues of Estimates of Area & Production of Principal Crops in West Bengal, Directorate of Agriculture, Govt. of W. B*

## Annexure: II

**Table 1. Rotated component matrix (a) of new alluvium sub-region**

| | Component | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Size of Urban Population | 0.899 | | 0.342 | 0.193 |
| Fertilizer Consumption | 0.896 | -0.174 | | 0.218 |
| Rural Literacy Rate | 0.896 | 0.213 | 0.246 | 0.275 |
| Small Landholder | 0.890 | 0.183 | 0.211 | 0.276 |
| Per Capita Income | 0.874 | -0.153 | 0.352 | 0.111 |
| Area Under HYV | 0.857 | | 0.156 | 0.296 |
| Number of Market | 0.806 | -0.273 | 0.181 | 0.347 |
| Road Length | -0.646 | -0.614 | -0.347 | -0.174 |
| Irrigation | -0.148 | 0.944 | | -0.104 |
| Annual Rainfall | -0.286 | | -0.941 | -0.117 |
| Relative Price | 0.436 | | 0.135 | 0.879 |

*(a) Rotation converged in 8 iterations.*

**Table 2. Rotated component matrix (a) of hill sub region**

| | Component | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Small Landholder | 0.967 | | | |
| Rural Literacy Rate | 0.934 | -0.233 | 0.210 | |
| Relative Price | 0.913 | 0.191 | | -0.126 |
| Size of Urban Population | 0.709 | -0.489 | 0.388 | 0.217 |
| Road Length | -0.656 | 0.529 | 0.416 | 0.217 |
| Per Capita Income | 0.643 | -0.528 | 0.480 | 0.143 |
| Fertilizer Consumption | 0.229 | 0.910 | -0.109 | -0.154 |
| Irrigation | -0.435 | 0.716 | 0.183 | -0.163 |
| Number of Market | -0.145 | 0.579 | -0.439 | 0.228 |
| Area Under HYV | 0.102 | | 0.816 | -0.216 |
| Annual Rainfall | | -0.102 | -0.203 | 0.922 |

*(a) Rotation converged in 5 iterations.*

**Table 3. Rotated component matrix (a) of Terai sub –region**

| | Component | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Number of Market | -0.906 | -0.340 | -0.188 | |
| Road Length | -0.888 | -0.196 | -0.184 | 0.172 |
| Small Landholder | 0.865 | 0.459 | 0.150 | |
| Rural Literacy Rate | 0.856 | 0.416 | 0.240 | |
| Irrigation | 0.854 | 0.451 | 0.176 | |
| Area Under HYV | 0.703 | 0.510 | 0.401 | 0.129 |
| Fertilizer Consumption | 0.377 | 0.812 | 0.175 | 0.144 |
| Per Capita Income | 0.450 | 0.803 | 0.309 | -0.105 |
| Size of Urban Population | 0.473 | 0.756 | 0.342 | -0.101 |
| Relative Price | 0.298 | 0.391 | 0.859 | -0.109 |
| Annual Rainfall | | | | 0.985 |

*(a) Rotation converged in 9 iterations.*

**Table 4. Rotated component matrix (a) of old alluvium sub-region**

| | Component | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Area Under HYV | 0.953 | | 0.154 | 0.141 |
| Road Length | -0.875 | -0.314 | | |
| Small Landholder | 0.841 | 0.391 | | |
| Irrigation | 0.770 | | 0.421 | |
| Rural Literacy Rate | 0.727 | 0.672 | 0.103 | |
| Size of Urban Population | 0.132 | 0.965 | | |
| Per Capita Income | 0.413 | 0.888 | | |
| Fertilizer Consumption | 0.374 | 0.855 | | 0.108 |
| Annual Rainfall | 0.122 | -0.747 | -0.549 | |
| Relative Price | 0.356 | -0.112 | 0.867 | |
| Number of Market | | | | 0.990 |

*(a) Rotation converged in 5 iterations.*

**Table 5. Rotated component matrix (a) of coastal saline sub region**

| | Component | | | |
|---|---|---|---|---|
| | **1** | **2** | **3** | **4** |
| Size of Urban Population | 0.952 | 0.165 | -0.119 | |
| Number of Market | 0.935 | 0.224 | | |
| Per Capita Income | 0.930 | | -0.119 | |
| Rural Literacy Rate | 0.859 | 0.477 | -0.111 | |
| Irrigation | 0.765 | | 0.336 | -0.139 |
| Small Landholder | 0.754 | 0.609 | -0.139 | |
| Relative Price | 0.517 | 0.299 | | 0.202 |
| Road Length | | -0.853 | -0.142 | |
| Fertilizer | 0.361 | 0.625 | -0.180 | -0.114 |
| Annual Rainfall | | | 0.959 | |
| Area Under HYV | | -0.124 | | 0.958 |

*(a) Rotation converged in 6 iterations*

**Table 6. Rotated component matrix (a) of red-laterite sub-region**

| | Component | | | |
|---|---|---|---|---|
| | **1** | **2** | **3** | **4** |
| Per Capita Income | 0.958 | 0.121 | | -0.156 |
| Rural Literacy Rate | 0.903 | 0.292 | 0.280 | |
| Fertilizer | 0.894 | -0.148 | 0.303 | |
| Size of Urban Population | 0.819 | -0.175 | -0.387 | -0.257 |
| Area Under HYV | 0.796 | 0.387 | | -0.102 |
| Small Landholder | 0.746 | 0.446 | 0.407 | |
| Road Length | -0.111 | -0.898 | | |
| Relative Price | 0.128 | 0.757 | | |
| Number of Market | | | 0.944 | |
| Irrigation | -0.139 | 0.408 | -0.568 | 0.457 |
| Annual Rainfall | -0.134 | | | 0.948 |

*(a) Rotation converged in 5 iterations.*

**Table 7. Rotated component matrix (a) of eastern plateau & hilly zone**

| | Component | | | |
|---|---|---|---|---|
| | **1** | **2** | **3** | **4** |
| Size of Urban Population | 0.956 | -0.180 | 0.149 | -0.147 |
| Rural Literacy Rate | 0.949 | 0.154 | 0.119 | -0.184 |
| Per Capita Income | 0.938 | -0.166 | 0.169 | -0.149 |
| Small Landholder | 0.929 | 0.300 | | |
| Area Under HYV | 0.887 | | -0.134 | 0.204 |
| Number of Market | 0.646 | 0.414 | 0.570 | |
| Irrigation | -0.110 | -0.927 | | -0.113 |
| Fertilizer | -0.523 | 0.674 | 0.279 | |
| Road Length | 0.263 | | 0.854 | |
| Relative Price | 0.388 | 0.465 | -0.621 | -0.120 |
| Annual Rainfall | -0.111 | | | 0.977 |

*(a) Rotation converged in 10 iterations; Note: 1. Extraction Method: Principal Component Analysis.*
*2. Rotation Method: Varimax with Kaiser Normalization*



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