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Trend Surface Analysis of Sex Ratios of Population, West Bengal, 1991-2011

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Abstract

Crude Sex Ratio and Child Sex Ratio have been the most discussed gender indices in recent times. However, a disaggregated study of sex ratio of different social groups, literates and workers definitely gives a clear picture of the social matrix of the study area and the associated social, economic, historical and political impact on the participation of the females in the different spheres. The present study aims at studying the district wise variation of different sex ratio (Crude, Rural, Child, Scheduled Caste, Scheduled Tribe, Literate, Worker, Main Worker and Marginal Worker population) of West Bengal, explain the reasons for the present pattern and their nature of change from 2001 to 2011. The study also investigates the impact of geographical location on the variables and generates trend surfaces based on the block-level data. The variation in the variables is well explained by the trend surface regression equations, which have a high level of significance. Thematic maps and trend surface plots have supplemented the results.

Introduction

Studies by Sen (2001), Agnihotri (1995), Bongaarts and Guilmoto (2015), show that missing women have been on the rise and the number is expected to peak at 150 million in 2035. The United Nations have marked Gender Equality as one of the most important goals in the Sustainable Development Goals, which was previously a vital goal in the Millennium Development Goal. According to the UN, "gender equality is not only a fundamental human right but a necessary foundation for a peaceful, prosperous and sustainable world" (United Nations Sustainable Development, 2018).

Post Amartya Sen's seminal work on 'Million Missing Girls' (1990), study of Female-Male Ratio (FMR) have gained immense importance worldwide as well as in India. India's present FMR at 935, ranked at 192 out of 201 nations whereas Asia's value stands at 954 and the World figure is 983 (World Bank, 2015).The true nature of India's FMR can be comprehended only by looking into its nature in history which should be further disaggregated to understand the control of certain states on the national data. The very fine geographic differentiations make it possible to discern the phenomena concerned, their constraints and actors (Guilmoto, 2007).

Although geographers are traditionally concerned with the description, analysis and explanation of areal distributions of phenomena, much of the most vigorous development of new techniques in the field has come from outside geography. Both graphical or grid techniques and also complex computer programmes should be widely adopted for use in all branches of geography, both physical and human, in the immediate future (Chorley & Haggett, 1965). The analysis of point patterns on a sphere, or line patterns, or networks, or area patterns, etc are possible in Geographic Information Systems (GIS), but geographic analysts face problems like integrating population behaviour into the social matrix, that is different from those that occur in geophysics.

Objective

The present study aims at studying the district wise variation of different categories of sex ratio (Crude, Rural, Child, Scheduled Caste, Scheduled Tribe, Literate, Worker, Main Worker and

Marginal Worker population) of West Bengal, attempts to explain the reasons for the present pattern and their nature of change from 2001 to 2011. The study also investigates the impact of geographical location on the variables and generates trend surfaces based on the block level data.

Methodology

Over the past few centuries, geographically referenced data has been consciously integrated into the conceptual framework and applications of social science and humanities. Introduced primarily by Oldham and Sutherland (1955) Trend Surface Analysis (TSA), based on polynomial regression was used by Dessaint and Caussanel (1994) to describe the spatial pattern of a weed community in a cornfield. Moos and Randall (1995) suggested an effect of geographic latitude in regard to the frequency of conception in human populations with TSA. Similarly Cohen and Small (1998) studied the impact of latitude, longitude and altitude on population distribution and concluded that the median person lived at an elevation of 194 m above sea level and the population density within 100 vertical meters of sea level was significantly larger than that of any other range of elevations and represented far more people.The study uses sensitivity mapping and trend surface analysis for understanding the nature and inter-district variability of sex ratio over the different subcategories of population. The sex ratio is calculated as number of females per thousand males.

Sensitivity Analysis

To estimate the nature of change the districts have experienced in the inter-Censal period of 2001 – 2011, firstly the change of sex ratio from 2001 to 2011 was calculated. The results were standardized with respect to the arithmetic means and standard deviation and the modulus value was summed up to get the sensitivity index (Si_d) as follows:

$$Si_d = \text{Sum of } (z_{SRt1} \sim z_{SRt2})$$

Where, z= standardized values of sex ratio at time t_1 and t_2

As the magnitude for the different sets of components varies widely, there was a need to standardize the data. Once standardized, the summation indicated the level of sensitivity. Higher the value, greater the sensitivity, higher the propensity of the object/district to change over a span of time. Greater sensitivity also implies higher variability and erratic changes. It is noted that only the magnitude of the standardized value is considered to stress on the scale and significance of the absolute change. However, the method ignores the direction of change, i.e. its positive or negative nature. Thus, a higher value will indicate its magnitude can mislead to interpret high positive change, high negative change and moderately high and negative change in the same class. To eliminate this error, the positive and negative values are dealt with separately and two different Sensitivity Index have been calculated: the positive SI and the negative SI.

Trend Surface Analysis

Trend Surface Analysis (TSA) is performed to understand the control of geographical location on particular FMR. Trend surface analysis is the areal regression where the effect of spatial coordinates (latitude and longitude) is studied over a response. Here the different types of FMR s are studied to capture the changes in their values according to the spatial coordinates, at the block level. Suppose, the longitude and the latitude of any block of West Bengal be denoted respectively by *x* and *y* and the FMR is denoted by *z*. Then, to fit a trend surface of certain order *n*, a linear regression of z is fitted on different orders of *x* and *y* from order 1 to order *n* along with an intercept term and all possible interaction terms. For example, the first-order trend surface of an FMR (*z*) can be written as a trend surface equation of the form:

$$z = a_0 + a_1 x + a_2 y \qquad (1)$$

Where, a_0 is the intercept term and a_1 and a_2 the regression coefficients corresponding to *x* and *y* are and . The first order trend surface represents a plane where the regression coefficients determine the direction cosines or slopes of that plane.

Similarly, a *2nd* -order trend surface equation is of the form,

$$z = a_0 + a_1 x + a_2 y + a_3 y^2 + a_4 x y + a_5 y^2 \qquad (2)$$

Where, a_0 is the intercept term and a_2, a_3, a_4 and a_5 are the regression parameters corresponding to different components with varying powers of *x* and *y* are denoted by corresponding to the i^{th} component mentioned in the equation. Here the number of parameters is six for a second-order trend surface.

The 3rd order trend surface equation is of the following form,

$$z = a_0 + a_1 x + a_2 y + a_3 y^2 + a_4 x y + a_5 y^2 + a_6 x^2 + a_7 x^2 y + a_8 x y^2 + a_9 y^3 \qquad (3)$$

where the parameters may be described as above. Here, the number of parameters is ten, which were six for the second-order trend surface equation.

In a similar way, the fourth-order trend surface equation can be written as,

$$z = a_0 + a_1 x + a_2 y + a_3 y^2 + a_4 x y + a_5 y^2 + a_6 x^2 + a_7 x^2 y + a_8 x y^2 + a_9 y^3 + a_{10} x^4 + a_{11} x^3 y + a_{12} x^2 y^2 + a_{13} x y^3 + a_{14} y^4 \qquad (4)$$

where the numbers of unknown parameters are 15. However, for real-life data with lots of variations over different regions, i.e. containing a large number of irregularities over the entire regions is not suitable to fit by a surface fitting. In all of the above equations, the unknown parameters are estimated via the method of least squares.

For West Bengal, as per 2011 Census, there are 341 Community Development Blocks (CDB) in all. Asansol Kulti Township Economic Unit (EU) of Barddhaman district and Kolkata have been omitted due to its entirely urban character. So, to fit a trend surface using block-level data, there are 341 data points. A higher-order trend surface includes numerous parameters to estimate, also the interpretation of the various components are not feasible for higher-order surface fitting. Higher the order, higher is the number of parameters to interpret. Hence, a very high order trend surface is not feasible to interpret.

To measure the goodness of fit, the multiple R-squared (R^2) value, adjusted R^2 value and Akaike's Information Criterion (AIC) are generally considered. The multiple R^2 values indicate the percentage of variations explained by the predicted values over the total variations contained in the dataset (z). The adjusted R^2 value is a modification to the R^2 value where the number of parameters involved in the model penalizes the actual value. For comparing two different models, higher the adjusted R^2 value, better the fitting. Similarly, lower the AIC value better the fitting. In a trend surface fitting, the bordered area or the regions related to boundary points are prone to large residuals. Since the northern-central and the northern part of West Bengal has a limited longitudinal extent, the trend surface fitting for the entire regions of the state will be more erroneous due to the border effects. To nullify the effect, trend surface equations have been generated for the southern region separately (excluding the chicken's neck and the Himalayan districts), where the districts are comparatively consolidated.

The results from the Sensitivity Index and Trend surface analysis are mapped using Mapinfo Professional (v.13.0) and Surfer (v.11). The spatial outliers are identified by residual maps. For Sensitivity mapping, the SI_d is grouped with a class interval of 2 units and a district-wise choropleth map is prepared, with higher values bearing the darkest shade and lower values having the lightest. Accordingly, maps for positive SI and negative SI are also prepared. The spatial outliers are identified by residual maps. Grids were prepared by Inverse Distance to Power method in Surfer, with weighting power 2. The contour map was prepared with residuals, positive residuals bearing the shades of blue and negative residuals with shades of brown, intensifying with an increase in magnitude. The contour map was then superimposed on the district map of West Bengal to understand the specific regional characteristics. There remain certain cognitive and behavioural aspects of the society that cannot be quantified but is supremely vital in decision making at the household level. Hence, 'focus group discussions' (FGD) were conducted in Ondal, Dhaniakhali, Gosaba and Rangli-Rangliot to comprehend the underlying phenomenon governing the existing distribution in FMR.

Results

Sensitivity Index

For computation of the 'sensitivity index' values, Crude SR, Child SR, SC SR, ST SR, Literate SR and Worker SR for the Census years 2001 and 2011 have been considered and calculated at the district level. The consolidated, positive sum and negative sum SI was calculated and mapped. The highest SI was noticed in Kolkata (13.16), followed by Maldah (6.87) and Purba Medinipur (6.2).All three districts have a high propensity to change, with Kolkata recording a exceptionally high value (twice the value of the second ranking district), which characterizes and personifies the dynamic metropolitan outlier of the state capital. But, it is not clear if the change is negative or positive.

The segregated positive and negative SI maps give a clear picture. Kolkata is clearly having the highest negative SI, whereas Maldah and Purba Medinipur is classified under very high positive SI. Undoubtedly, all three districts cannot be classified under the same group and will have disparate and divergent characteristics. Purba Medinipur (6.2), Maldah (5.23), Nadia (4.99) and Koch Bihar (4.01) display very high positive SI. Kolkata (13.06) records extremely high negative SI followed by Haora (4.17) and Paschim Medinipur (4.11). Uttar Dinajpur have displayed both moderately high positive SI and moderately high negative SI. The districts of Jalpaiguri, Dakshin Dinajpur, Murshidabad, Birbhum, Bardhaman and Hugli neiher have a significant high positive SI, nor a high negative SI. In other words, these have very low SI and are less likely to change over time. The Sex Ratio in these districts have attained a stability. Though to be definite about it more temporal data points should be taken into account.

Trend Surface Analysis

The result of the trend surface fitting can be represented in the following table where the four columns are corresponding to the first, second, third and the fourth order trend surfaces respectively and the different rows correspond to different FMR is considered for the state WB. Each cell corresponding to a particular type of FMR and a fixed order trend surface contains the R^2 value, which is the percentage of variations explained by the predicted values along with an indication of level of significance. Although, in most of the cases where the model fittings are significant, the percentage of variations explained are negligible compare to total variation. It is also noticed that the trend surface results are inadequately extrapolated for the blocks with less neighbours, i.e, the blocks that are at the edges or the border blocks. Thus, the residual plots for the borders are represented inadequately. For this study those cases are further investigated where R^2 value is greater than 0.5. For the trend surfaces generated, Literate FMR, Main Cultivator FMR, Main Agricultural Labour FMR and Main Workers (Others) FMR have their variations explained significantly. Residual plot for trend surface fitting for these FMRs are given in the appendix.

For those cell values for which the multiple R^2 value is not so small, the detailed model parameters are given further in Table 1 and Table 2. For those cases, the trend surface can be fitted by excluding those blocks that are at chicken's neck portion of West Bengal. It is observed that after excluding the chicken's neck portion from the calculation, most of the response variables have shown a significant increase in explained variation.. The Worker FMR and Main Worker FMR , which was poorly explained for the whole of WB, have seen a comparative improvement when the chicken's neck portion was eliminated whereas, Main Worker Cultivator and Main Worker Others, have significantly reduced explained variation in the latter case. For both Trend Surface (whole WB) and Trend Surface (excluding chicken's neck and above) the Literate FMR have most of the variation explained and it can be concluded that the pattern of literacy is particularly influenced by its location.

Discussion

Since the sensitivity index is calculated based on change in the intercensal period, it can be taken as a measure of temporal change. Similarly, the trend surface results are an expression of the spatial variation. The author seeks to appraise not only the spatio-temporal character but also discover the relationship between the temporal pattern and the spatial pattern.

Low sensitivity values for both positive and negative values

correspond to lower residuals. That means sex ratios of regions that have lower temporal variation are more accurately predicted by trend surface equations. Example, Birbhum, Dakshin Dinajpur and Murshidabad. Regions having high sensitivity values for both positive and negative values correspond to high negative residual, which implies that higher the temporal variation, higher will be its probability to deviate negatively from the predicted value to their highest order of surface equation with highly significant coefficient of determination. Example, Uttar Dinajpur. Regions with only positive sensitivity and no negative sensitivity records moderately high and moderately low residuals thus the region is characterized by high spatial variation and that too in two opposite directions. Example, Koch Bihar, Nadia and Purba Medinipur.

From all the Focus Group Discussions it is evident that there are phenomena beyond the numbers which needs investigation. The impact of local geography leaves an indelible mark on the population characteristics. Migration emerge as an important factor However, the principal factor that comes forward is the perception and attitude of both men and women, which play an instrumental role in defining the life cycle of women in the patriarchal and patrilineal society which conditions men and women to their present status through traditions and rituals and the most horrific acts of inhumanity to women seem natural. As a matter of fact, social vices (like dowry, infanticide, domestic violence, molestation, etc.) can only be wiped out, if an only if, it is acknowledged as an untoward and unsocial incident. It remains a duty on the part of the government to inform and spread awareness regarding the right and wrong and social evils. It is also to be acknowledged that social and cultural modifications cannot be achieved within a span of a decade, thus policies towards social reform should be long term and not discontinuous schemes that change with the ruling party in the state.

It has also been observed that in the districts lower courses of river, having a very fertile land, specially in the eastern plains, the competition for land is very high. And this competition is not only within the community but also within the household. Thus, subconsciously women are systematically eliminated from competition by depriving them from the basic rights like food and education, thus leaving them disempowered both physically and mentally. However in the relatively infertile districts like Puruliya and Darjeeling, the competition for land is less. Men outmigrate in search of work and the women are left behind to tend to household chores. Work participation of women in peri-urban areas of Kolkata, Asansol-Durgapur and Siliguri has been found to be particularly low, in relation to men as pointed out by Sen (2016). This, in part, conforms to the studies in developing countries, women have hardly gained from the economic dynamism in the peri-urban areas (Lanjouw, Quizon, & Sparrow, 2001).

Conclusion

Population is a dynamic entity and is prone to noticeable changes with the slightest trigger. Since, the trend surface analysis considers only one response variable at a time, interdependence of response variables are ignored. For a better representation of data, spatial regression can be used for a better explanation. Additionally, the same methods applied can be applied over a larger region (at the national level) with increased data points and more temporal variations to examine the universal applicability of the postulate.

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Table-1a: Coefficients of Determination and Level of Significance of Trend Surface Analysis, West Bengal

Categories Sex Ratios	Trend Surface (whole West Bengal)							
	1st Order		2nd Order		3rd Order		4th Order	
	p	R^2	p	R^2	p	R^2	p	R^2
Crude	0.079	0.01	0.033	0.04	0.000	0.16	0.000	0.25
Urban	0.000	0.05	0.000	0.07	0.000	0.10	0.000	0.18
Child	0.012	0.03	0.000	0.06	0.000	0.10	0.000	0.14
Scheduled Castes	0.000	0.06	0.000	0.17	0.000	0.41	0.000	0.48
Scheduled Tribes	0.069	0.02	0.138	0.02	0.221	0.03	0.405	0.04
Literates	0.000	0.51	0.000	0.71	0.000	0.76	0.000	0.78
Total Worker	0.000	0.28	0.000	0.36	0.000	0.45	0.000	0.48
Main Worker	0.000	0.22	0.000	0.27	0.000	0.32	0.000	0.36
Main Cultivator	0.000	0.13	0.000	0.41	0.000	0.46	0.000	0.52
Main Agricultural Labourer	0.000	0.29	0.000	0.40	0.000	0.52	0.000	0.59
Main Household Industries Worker	0.015	0.02	0.000	0.11	0.000	0.19	0.000	0.23
Main Other Workers.	0.000	0.24	0.000	0.39	0.000	0.50	0.000	0.57
Marginal Worker	0.000	0.20	0.000	0.27	0.000	0.37	0.000	0.47
Marginal Cultivator	0.000	0.19	0.000	0.29	0.000	0.31	0.000	0.45
Marginal Agriculture Labourers	0.000	0.27	0.000	0.46	0.000	0.53	0.000	0.67
Marginal Household Industries Worker	0.002	0.04	0.000	0.20	0.000	0.32	0.000	0.35
Marginal Other Workers	0.000	0.12	0.000	0.20	0.000	0.31	0.000	0.38
Non Working	0.000	0.42	0.000	0.53	0.000	0.63	0.000	0.66

Table-1b: Coefficients of Determination and Level of Significance of Trend Surface Analysis, West Bengal
excluding Chicken's Neck and North Bengal

Categories of Sex Ratios	Trend Surface (excluding chicken's neck and above)							
	1st Order		2nd Order		3rd Order		4th Order	
	p	R^2	p	R^2	p	R^2	p	R^2
Crude	0.245	0.01	0.026	0.05	0.000	0.29	0.000	0.33
Urban	0.000	0.06	0.000	0.10	0.000	0.19	0.000	0.23
Child	0.000	0.09	0.000	0.10	0.000	0.14	0.000	0.18
Scheduled Castes	0.000	0.11	0.000	0.32	0.000	0.37	0.000	0.45
Scheduled Tribes	0.086	0.02	0.099	0.03	0.212	0.04	0.426	0.05
Literates	0.000	0.65	0.000	0.83	0.000	0.86	0.000	0.86
Total Worker	0.000	0.35	0.000	0.40	0.000	0.61	0.000	0.67
Main Worker	0.000	0.15	0.000	0.18	0.000	0.46	0.000	0.60
Main Cultivator	0.000	0.27	0.000	0.34	0.000	0.37	0.000	0.44
Main Agricultural Labourer	0.000	0.45	0.000	0.57	0.000	0.65	0.000	0.67
Main Household Industries Worker	0.000	0.15	0.000	0.33	0.000	0.41	0.000	0.44
Main Other Workers.	0.108	0.02	0.000	0.16	0.000	0.38	0.000	0.42
Marginal Worker	0.000	0.12	0.000	0.15	0.000	0.32	0.000	0.44
Marginal Cultivator	0.001	0.05	0.000	0.11	0.000	0.16	0.000	0.19
Marginal Agriculture Labourers	0.000	0.51	0.000	0.58	0.000	0.64	0.000	0.66
Marginal Household Industries Worker	0.000	0.22	0.000	0.35	0.000	0.38	0.000	0.42
Marginal Other Workers	0.000	0.12	0.000	0.24	0.000	0.32	0.000	0.40
Non Working	0.000	0.42	0.000	0.59	0.000	0.73	0.000	0.75

Source: Computed by the author, Census of India 2011 and 2001

Table - 2: Different Goodness-of-fit Criterion of Trend Surface Analysis

Categories of Sex Ratio	Order	Trend Surface (whole West Bengal)			Trend Surface (excluding chicken's neck and above)		
		R^2	adj R^2	AIC	R^2	adj R^2	AIC
Literate	1st	0.51	0.50	2664.75	0.65	0.65	2076.62
	2nd	0.71	0.71	2487.17	0.83	0.83	1881.35
	3rd	0.76	0.76	2429.29	0.86	0.85	1845.31
	4th	0.78	0.77	2413.44	0.86	0.86	1844.32
Worker	3rd	***0.45***	-	-	0.61	0.60	2545.75
	4th	***0.48***	-	-	0.67	0.65	2509.63
Main Worker	4th	***0.36***	-	-	0.60	0.58	2243.29
Main Cultivator	4th	0.52	0.50	2581.10	***0.44***	-	-
Main Agricultural Labour	2nd	***0.40***	-	-	0.57	0.56	2543.07
	3rd	0.52	0.50	3218.80	0.65	0.64	2495.21
	4th	0.59	0.57	3172.28	0.67	0.65	2490.86
Main Others	3rd	0.50	0.50	3218.80	***0.38***	-	-
	4th	0.57	0.57	3172.28	***0.42***	-	-

Source: Computed by the author

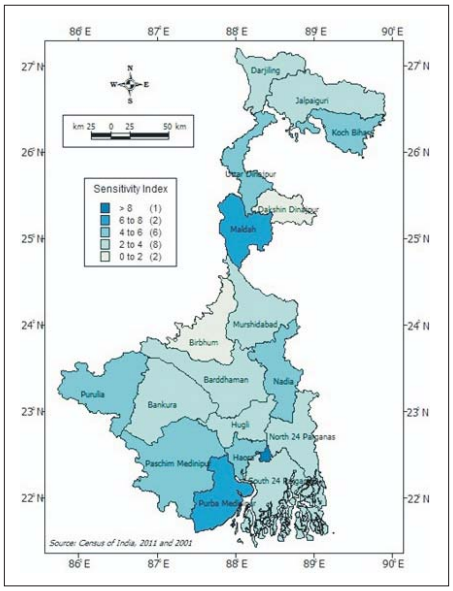

Fig. 1: Sensitivity Map

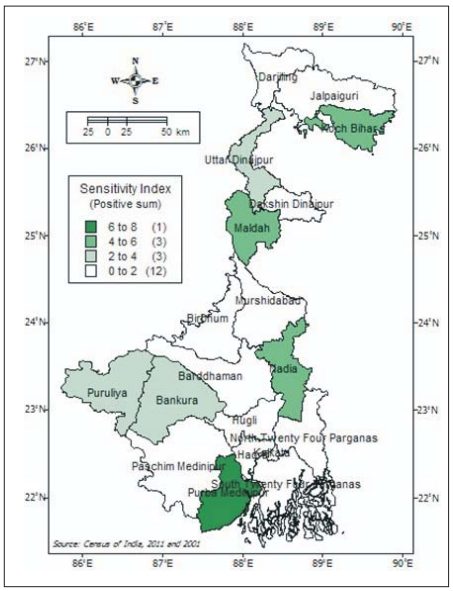

Fig. 2: Positive Sensitivity Map

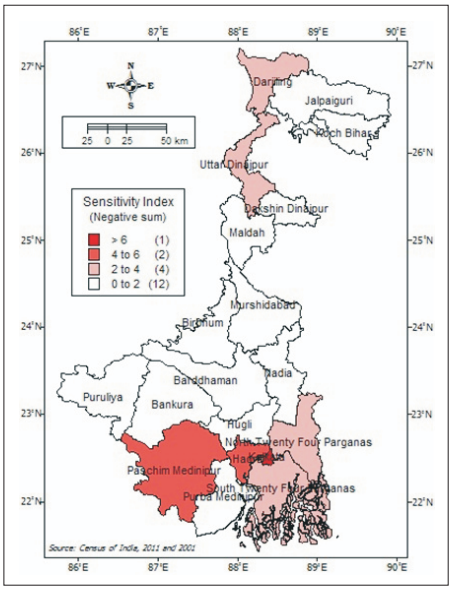

Fig. 3: Negative Sensitivity Map

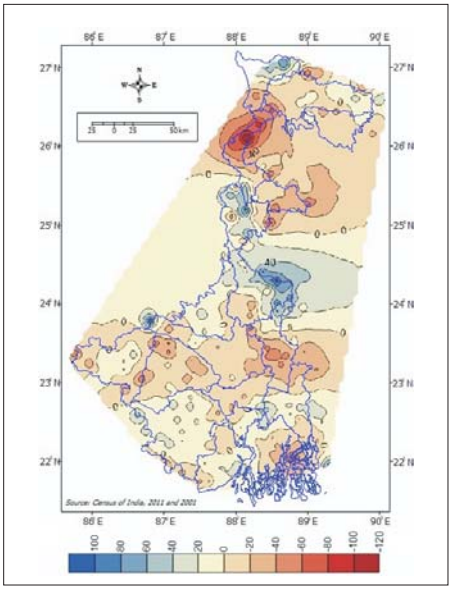

Fig. 4: Residual Map of 1st Order TSA of Literate SR, W.B., 2011

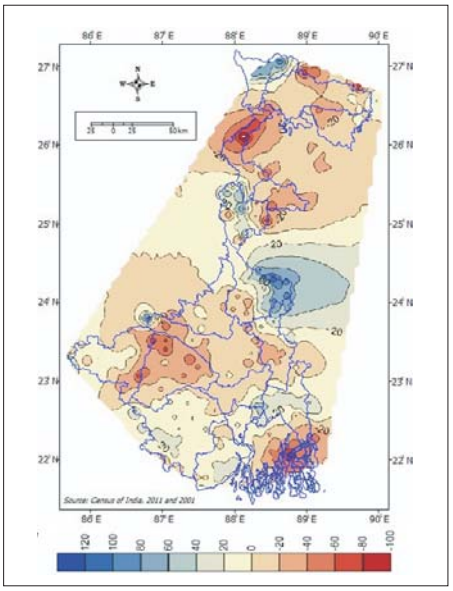

Fig. 5: Residual Map of 2nd Order TSA of Literate SR, W.B., 2011

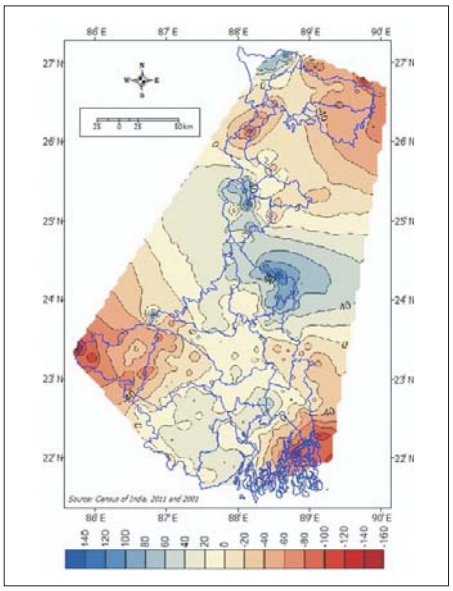

Fig. 6: Residual Map of 3rd Order TSA of Literate SR, W.B., 2011

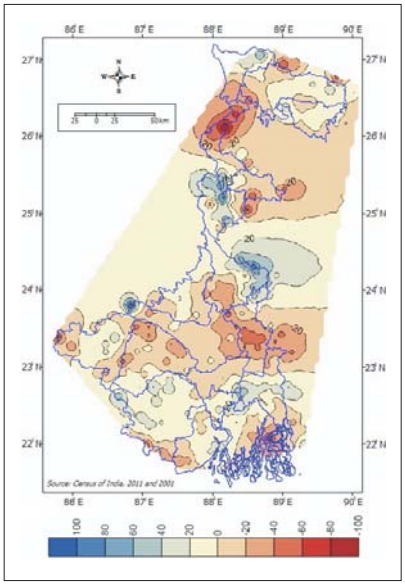

Fig.7: Residual Map of 4rd[t] Order TSA of Literate SR, W.B., 2011

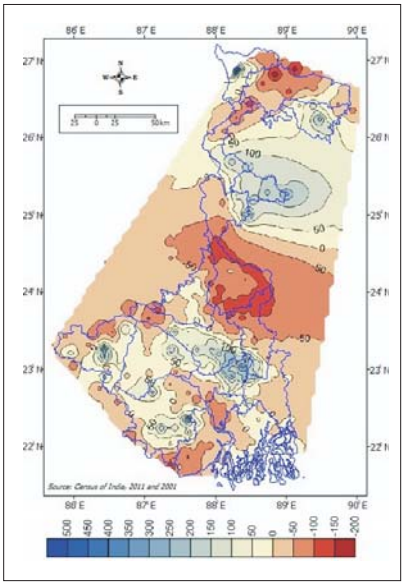

Fig.8: Residual Map of 3rd Order TSA of Main Agricultural Workers SR, W.B., 2011

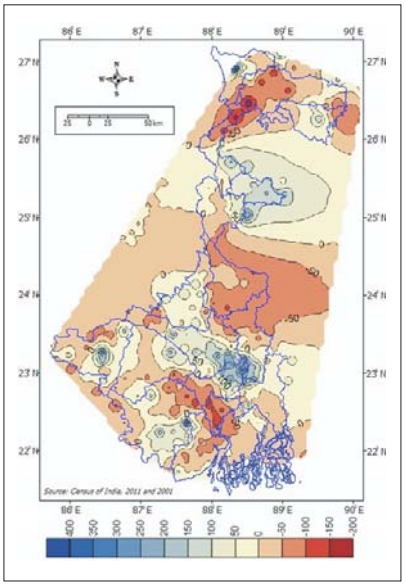

Fig.9: Residual Map of 4th Order TSA of Main Agricultural Workers SR, W.B., 2011

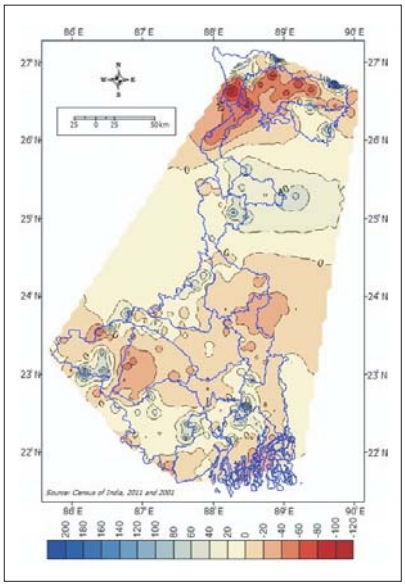

Fig.10: Residual Map of 4thOrder TSA of Main Cultivators SR, WB, 2011

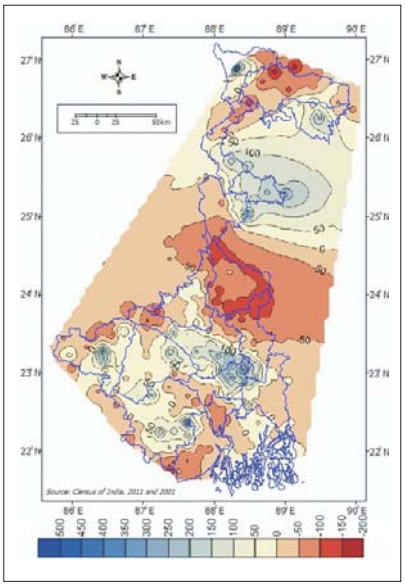

Fig.11:Residual Map of 3rd Order TSA of Main Workers Others SR, W.B., 2011

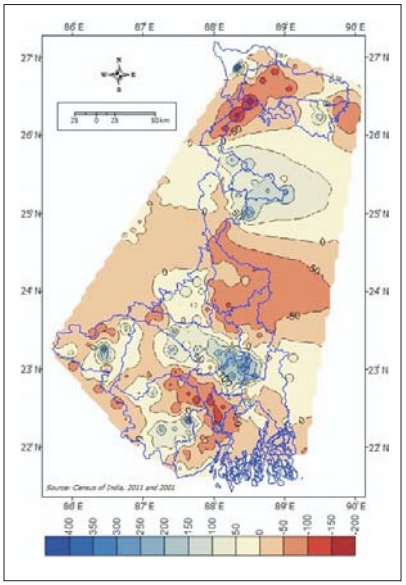

Fig.12: Residual Map of 4th Order TSA of Main Workers Others SR, W.B., 2011

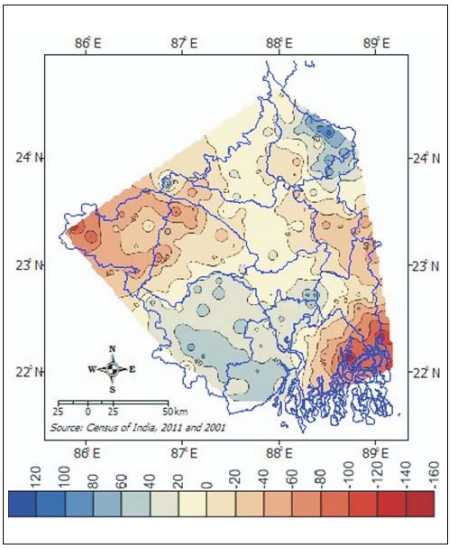

Fig. 13: Residual Map of 1st Order TSA of Literate SR, W.B (excluding Chicken's Neck and North Bengal), 2011

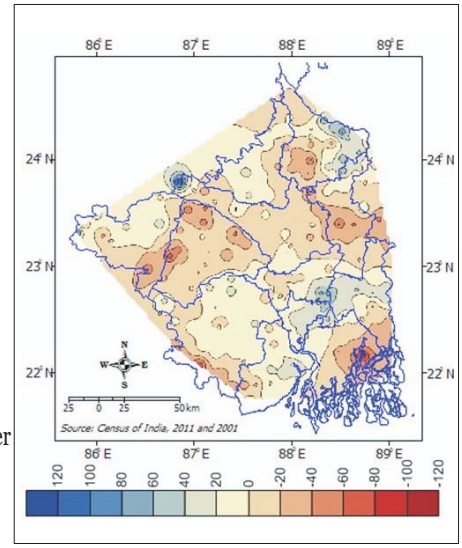

Fig. 14: Residual Map of 2nd Order TSA of Literate SR, W.B (excluding Chicken's Neck and North Bengal), 2011

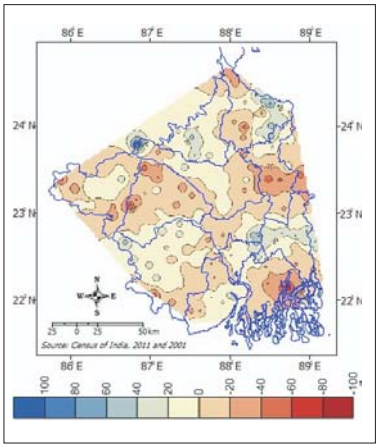

Fig. 15: Residual Map of 3rd Order TSA of Literate SR, W.B (excluding Chicken's Neck and North Bengal), 2011

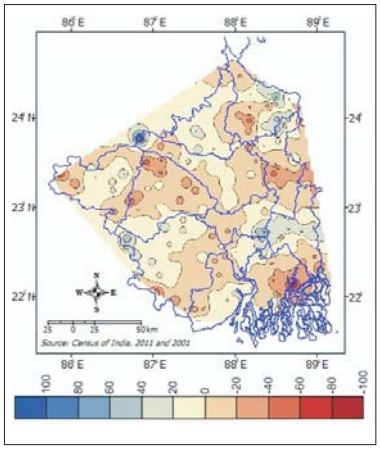

Fig. 16: Residual Map of 4th Order TSA of Literate SR, W.B (excluding Chicken's Neck and North Bengal), 2011

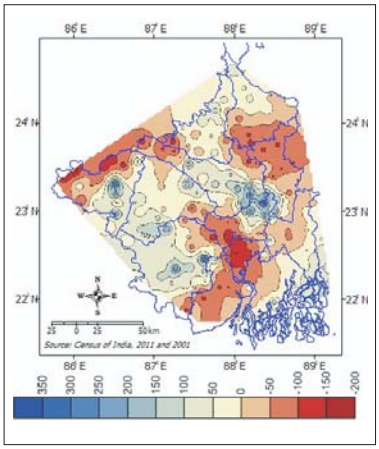

Fig. 17: Residual Map of 2nd Order TSA of Main Agricultural Worker SR, W.B (excluding Chicken's Neck and North Bengal), 2011

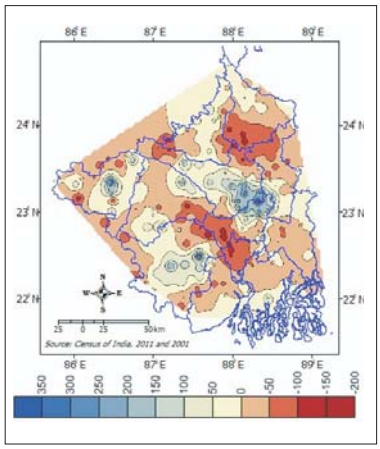

Fig. 18: Residual Map of 3rd Order TSA of Main Agricultural Worker SR, W.B (excluding Chicken's Neck and North Bengal), 2011

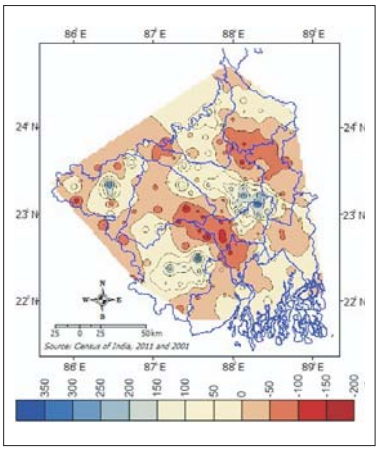

Fig. 19: Residual Map of 4th Order TSA of Main Agricultural Worker SR, W.B (excluding Chicken's Neck and North Bengal), 2011

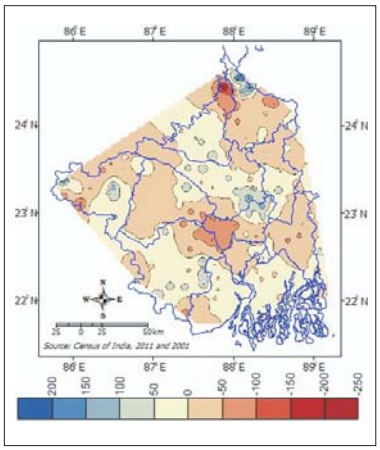

Fig. 20: Residual Map of 4th Order TSA of Main Worker SR, W.B (excluding Chicken's Neck and North Bengal), 2011

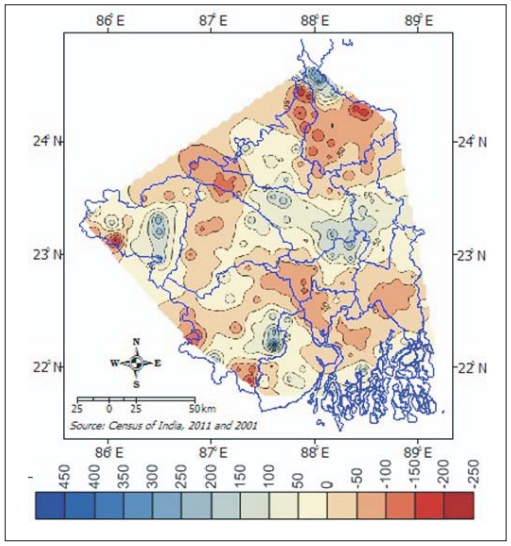

Fig. 21: Residual Map of 3rd Order TSA of Total Worker SR, W.B (excluding Chicken's Neck and North Bengal), 2011

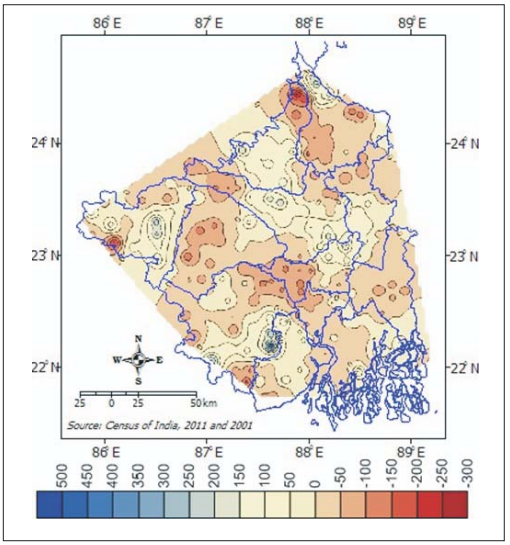

Fig. 22: Residual Map of 4th Order TSA of Total Worker SR, W.B (excluding Chicken's Neck and North Bengal), 2011