Statistical investigation on impact of climate change on rice in Odisha using Panel data.

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CERTIFICATE-I

This is to certify that the thesis entitled **"Statistical investigation on impact of climate change on rice in Odisha using Panel data"** submitted in partial fulfilment of the requirements for the award of the Degree of **MASTER OF SCIENCE IN AGRICULTURE (AGRICULTURAL STATISTICS)** of the Orissa University of Agriculture and Technology, Bhubaneswar is an authentic record of *bona fide* research work carried out by **JYOTIRMAYEE MURMU,** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the evidence and help obtained by her from various sources during the course of investigation has been duly acknowledged.

Jambhulkar

Place: Cuttack
Date: 21-06-2018

Dr. Nitiprasad Namdeorao Jambhulkar
Chairman
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CERTIFICATE II

This is to certify that the thesis entitled **"Statistical investigation on impact of climate change on rice in Odisha using Panel data"** submitted by **JYOTIRMAYEE MURMU,** Adm.No.10AS/16 to Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE** in the discipline of **AGRICULTURAL STATISTICS** has been approved by the students' Advisory Committee and the external examiner.

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Jyotirmayee Murmu

Date – 21·06·2018 **Jyotirmayee Murmu**

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LIST OF ABBREVIATIONS AND SYMBOLS

OLS	:	Ordinary least squares
BLUE	:	Best linear unbiased estimator
%	:	Percentage
FE	:	Fixed effects
RE	:	Random effects
PCSE	:	Panel corrected standard error
HCCME	:	Heteroscedastic consistent covariance matrix
GMM	:	Generalized method of moments
GLS	:	Generalized least square
FDI	:	Foreign Direct investment

ABSTRACT

Climate change is a matter of global concern as its major contribution is on agricultural crop. An attempt is made to study the impact of climate change on rice in Odisha using Panel data. The secondary data collected and aggregated to form balanced panel data set for the year 1995 to 2015 for 20 districts of Odisha. The present study was undertaken to find out the impact of change in climatic variables i.e. rainfall, average maximum temperature, average minimum temperature and relative humidity on production of rice by using district level panel data for Odisha from 1995-2015. The descriptive statistics used to study the variability in weather parameters. The weather variability is studied in all districts of Odisha. Balasore of Northern district has the highest rainfall with mean of 1655 mm. Nuapada district of western Odisha has the lowest rainfall with the mean rainfall of 1120 mm. Bolangir district of western Odisha has the highest mean maximum temperature with 33.36^{o}C. Puri district of Eastern Odisha has lowest mean maximum temperature of 31.02^{o}C and highest mean minimum temperature of 24^{o}C. Koraput district of southern Odisha has lowest average minimum temperature with the mean of 17.35^{o}C. Ganjam of eastern Odisha has highest relative humidity with the mean of 81.65% followed by Jagatsinghpur district of same eastern Odisha with a mean relative humidity of 80.41%. Bolangir of western Odisha has shown the lowest relative humidity of 67.69%. To study the impact of climate change on production panel data analysis has been done by using pooled estimator, fixed effects model and random effects model. Pooled effect model revealed that rainfall and temperature are not significant whereas relative humidity issignificant. Fixed effect model estimated that rainfall, maximum temperature, minimum temperature are not significant and relative humidity is significant. Random effects model estimated that rainfall, maximum temperature, minimum temperature are not significant but relative humidity is significant. Other methods like Parks method and Da-Silva method has also been used. Parks method shows that all weather parameters are significant. Da-Silva method revealed that rainfall, maximum temperature and minimum temperature are not significant. The study concluded that with the increasing maximum temperature and decrease in rainfall the production of rice is adversely affected. The decrease in minimum temperature and fluctuation in relative humidity affect the production.

INTRODUCTION

Panel data is one of the important fields in econometrics. The possibility of modeling more realistic behavioral hypothesis and challenging methodological issues together with the increasing availability of panel data have led to the phenomenal proliferation of studies on panel data. Panel data is a dataset in which the behaviors of entities are observed across time. It is also known as longitudinal or cross sectional time series data. Panel data analysis is an increasingly popular form of longitudinal data analysis among social and behavioral science researchers. It studies the subject with multiple sites, periodically observed over a distinct time frame. This analysis enabled researchers to undertake longitudinal analysis in a wide variety of fields. It has its important significance in the field of social science, epidemiology, political science and psychology. It stabilizes to study the dynamics of change with short time series with repeated observations of cross-sections. It enhances the quality and quantity of data in ways that would be impossible using only one of these two dimensions. Panel data analysis endows regression analysis with both a spatial and temporal dimension. The spatial dimension pertains to a set of cross-sectional units of observations. These could be countries, states, firms, and commodities, group of people or even individuals. The temporal dimension pertains to periodic observations of a set of variables characterizing cross sectional units over a particular time span. Panel data is useful with observations that span both time and individuals in a cross section; more information is available giving more efficient estimates.It allows empirical tests of a wide variety. It can include variables at different levels of analysis suitable for multilevel or hierarchical model. An advantage of panel data is that time effects can be incorporated to control for these and other unobservable, although this will be a more effective strategy, the more plausible is the assumption that technology etc are common across the regions. These data sets provide relevant sources of information about the economy. The analysis of panel data allows the model builder to learn about economic processes while accounting for both heterogeneity across individuals, firms, countries, and so on and for dynamic effects that are not visible in cross sections. There are two types of dataset balanced and unbalanced. A dataset is known to be an unbalanced panel if the data set is having missing observations and a balanced dataset is a set that contains all elements observed in all time frames.Panel data provide the possibility of learning an individuals' behavioral by observing the behavior of others. It also simplifies computation and statistical inference as it involves two dimensions, a cross-sectional dimension and time series dimension.The analysis of panel or longitudinal data is the subject of one of the most active and innovative bodies in econometrics because panel data provide such a rich environment for the development of estimation techniques and theoretical results. With panel data it can be studied different issues: - Cross sectional variation vs. time series variation, heterogeneity, hierarchical structures dynamics in economic behavior, individual or group effects. It has different kinds of panel model structures i.e. pooled regression where a variable contains only a constant term and then ordinary least squares provide consistent and efficient estimates of the common intercept and the slope. Fixed effects estimates where a variable is unobserved but correlated with another variable and least squares estimator of parameter is biased and inconsistent as a consequence of an omitted variable. Greene (2008) concludes that the main advantage of panel data is that one can formally model the heterogeneity across groups that are typically present in panel data. Baltagi (2005) confirms this in his statement that the first benefit of panel data is “controlling for individual heterogeneity”. Panel data are better able to study the dynamics of adjustment. Panel data are better able to identify and measure effects that are simply not detectable in pure cross-section or pure time-series data. Panel data allow for the construction and testing of more complicated behavioral models than purely cross-section or time-series data.

Agriculture is one of the economic sectors most sensitive to weather fluctuations and extreme events since temperature and precipitation are direct inputs in agricultural production. Odisha is one of the vulnerable states to climate change in India and will become even susceptible in future. Climate change has already impacted on the life and livelihoods of the people in the coastal areas in the arid and semiarid regions. Effects of climate change on agriculture and other sectors are already evident. The agricultural sector is most likely to face significant yield reduction in future due to climate variability. Crop agriculture is the most vulnerable to climate change among different districts in Odisha economy. One major determinant of fluctuations in crop yield is year to year changes in climate variables. Climate change is the most crucial factor in the production of rice. It is a matter of global concern because of its impending threats to sustainable economic development.

Agriculture is more sensitive to climate change. Rainfall, temperature and relative humidity plays a croissant role as climatic inputs in crop growth. A deviation of any of these from the required exposure during the crop growing period has harmful impact on production systems. Several studies have been conducted to analyze the impact of climate change on the yield of crops. Most of these studies either adopted Crop Modeling Approach or Ricardian Approach to achieve its objective. Here in this study panel data method has been used to study the impact of climate change in rice production.As rice is the staple food crop in Odisha, it is crucial factor to know the impact of climate change on its production.

Rice is central to the lives of billions of people around the world. India is the 2ndlargest producer of rice in the world.Agriculture in Odisha to considerable extent means growing rice. Rice covers about 86% of the total cultivated area under rice. It is the staple food of almost the entire population of Odisha; therefore, the state economy is directly linked with improvements in production and productivity of rice in the state. In the 1950s Odisha was a leading rice-producing state in the country and it used to supply a sizable amount of rice grain to the central pool of food stocks. However, during the last 35 years, the state's rice area has stagnated around 4 million hectares, about 10% of the total rice area of the country. Odisha's share in the country's rice production was more than 11% in whichgradually declined to 7.9% in 2008-09. Rice in Odisha is now grown on an area of 4.4 million hectares, which accounts for 91% of the area under cereals and contributes about 94% of total cereal production in the state. In this state, rice is cultivated in almost 65% of cropping area.Odisha ranks 5thposition with the production of 8.29 million tonnes in 2014-15.

Aim and Scope of Study:

The main aim of this study is to investigate the impact of climate change on rice production in Odisha using Panel data. Climate change is the most crucial factor for the cultivation as well as production. Panel data methods have been used to study its impact on climate change on rice in Odisha.

Objective of Study:

1. To study the variability of weather parameters
2. To study the impact of change in weather variables on rice in Odisha

REVIEW OF LITERATURE

Panel data is a dataset in which the behaviors of entities are observed across time. It is also known as longitudinal or cross sectional time series data. Panel data analysis is an increasingly popular form of longitudinal data analysis among social and behavioral science researchers. Longitudinal data allow researcher to analyze a number of important economic questions that cannot be addressed using cross sectional or time series dataset. The power of panel data derives from their theoretical ability to identify the effects of specific actions, treatments or more general policies. It studies the subject with multiple sites, periodically observed over a distinct time frame. This analysis enabled researchers to undertake longitudinal analysis in a wide variety of fields. It has its important significance in the field of social science, epidemiology, political science and psychology. It stabilizes to study the dynamics of change with short time series with repeated observations of cross-sections. It enhances the quality and quantity of data in ways that would be impossible using only one of these two dimensions. Panel data analysis endows regression analysis with both a spatial and temporal dimension. The spatial dimension pertains to a set of cross-sectional units of observations. These could be countries, states, firms, and commodities, group of people or even individuals. The temporal dimension pertains to periodic observations of a set of variables characterizing cross sectional units over a particular time span. Panel data is useful with observations that span both time and individuals in a cross section; more information is available giving more efficient estimates. According to Marc Nerlove (2002), the fixed effects model of panel data techniques originated from the least squares methods in the astronomical work of Gauss (1809) and Legendre (1805) and the random effects or variance-components models, with an English astronomer George Biddell Airy, who published a monograph in 1861, in which he made explicit use of a variance components model for the analysis of astronomical panel data. The next stage is connected to R. A. Fisher, who coined the terms and developed the methods of variance and analysis of variance (ANOVA) in 1918; he elaborated both fixed effects and random effects models.

Lazarsfeld *et al*. (1938) coined the term ‘panel study’ in marketing in the effect of radio advertising on product sales.

Hausman *et al*. (1981) used weighted instrumental variables, based only on the information within the model, for random effects estimation to be used when there are enough instruments for the modeling.

Chamberlain (1982) showed that one way to estimate a whole range of panel data models was to summarize the data regressing all the endogenous variables on all of the exogenous variables obtaining an estimate of the reduced form of 2^{nd} matrix and the to test various restrictions on 2^{nd} matrix.

Hsiao (1986) proposed one of the benefits of panel data sets where it provides much larger data sets with more variability and less collinearity among variables compared to typical of cross-section or time series data alone. In addition, he also mentioned other benefits of panel data including panel data sets are more informative and able to control for individuals' heterogeneity. Controlling for individual heterogeneity is necessary because it is can cause to bias estimate.

Kasprzyk *et al*. (1989) said that limitations in panel data sets include problems in the design, data collection and data management of panel surveys. These include the problems of coverage or also known as incomplete account of population of interest, non-response which might be due to the lack of cooperation among respondent or might because of interviewer errors, recall because some of respondent are not remembering correctly, frequency of interviewing, interview spacing, reference period, the use of bounding to prevent the shifting of events from outside the recall period into the recall period and time in sample bias.

Bond *et al*. (1991) proposed a GMM estimator which is suitable for panel data with greater number of observation (n). Under the random effects model, GLS based on the true variance components is BLUE, and all the feasible GLS estimators considered are asymptotically efficient as n and t approaches to infinity.

Davidson *et al*. (1993) studied the fixed effects estimators depend only on deviations from their group means and referred as within-groups estimators.

Baltagi *et al*. (1995) derived the asymptotic mean square prediction error for the FE and RE and compared their performance using Monte Carlo simulations.

Baltagi *et al*.(1999) modified unbalanced panel and equally spaced data. Autocorrelation had been found across all panels. There are provisions for specifying the type of autocorrelation. An auto regression on lags of the residuals may indicate the presence or absence of autocorrelation and the need for dynamic panel analysis.

Greene (2002) studied the fixed effects model also known as the within estimator and assumption that the error term is correlated with the individual specific term α, because the model can exclude time-invariant variables (as gender, race etc.) or these variables could be omitted from the model.

Jennissen (2003) used a panel data for Western European countries over a period from 1960 to 1998 to estimate the influence of economic determinants on net international migration, and found that GDP per capita has a positive effect and unemployment a negative effect on international migration

Bauer *et al*. (2004) conducted a study on the predictability of stock return in a panel data of individual stocks and perform misspecification test related to the cross industry heterogeneity. Econometric model that they used can deal with unbalanced panel data, cross sectional correlation among prediction errors and industry specific time effect.

Drukker *et al*. (2005) examined the threshold effect of the super-neutrality of money by using a new panel-data methodology.

Farsi *et al*. (2005) applied panel data models in order to find the efficiency of the electricity distribution sector. They compared the estimated coefficients and efficiency of scores across three different panel data models. They used generalized least square, maximum likelihood estimation and random effects models.

Mariel *et al*. (2006) estimated parameters of demand equation by applying different types of statistical methodologies using panel data from German car industry. They focused on advertising variables. The important conclusion from their project paper was advertising play an important role but the effectiveness depends on message.

Raymond (2007) estimated the economic impact of climate change on Indian agriculture. A random year-to-year variation in weather data on agricultural output using a 40-year district-level panel data set covering over 200 Indian districts had been used. The econometric strategy Semi-Ricardian method had been used. Generalized least squares estimation of fixed effects model had been used.

Falk *et al*. (2008) investigated a panel data analysis on FDI and exports. The data link between exports and the outward FDI stock using a panel of industries and seven EU countries for the period 1973-2004 had been taken.

Mythili (2008)studied acreage and yield response for major crops in the Pre- and Post-reform periods in India using dynamic panel data. The estimation is based on dynamic panel data technique using pooled cross-sectional time-series data across the states of India for the period 1970-71 to 2004-05.

Das *et al*. (2009) examined the impact of agricultural credit on agricultural production that finds the role of direct and indirect agriculture credit by taking regional disparities in agriculture, credit disbursement and production. Dynamic panel data analysis using Arellano-bond regression had been taken to estimate it.

Goshal (2012) attempted to examine the growth, poverty and inequality paradox in India by using panel data approach by taking temporal and cross state behavior. Panel regression analysis had been used to estimate it.

Petit *et al*. (2012) studied panel data analysis in tourism research by using dynamic panel data model. Fixed effects model had been used to estimate the relationship between explanatory and dependant variables within one individual group. Least square dummy variable is used to estimate it.

Amarendra *et al.* (2013) examined the study on indicators of success on the PGA tour taking scoring average and earnings serve as the two primary indicators. The key performance statistics influence the system of earnings in place, earnings, or earnings per event and have weaker correlations to these variables than scoring average. The empirical study considers another indicator of success: top ten finishes per event played. Panel Data regressions are used to compare models for scoring average, earnings per event, and top ten finishes per event.

Sanjaya *et al*. (2013) analyzed the inflows of FDI as key factor on economic growth with panel data for the time period 1991-2010. Three different models like Fixed Effects Model, Random Effects Model and PCSE were used for the analysis.

Prasert *et al.* (2014) examined the production of Thailand's sugarcane using panel data envelopment analysis based decision on bootstrapping method using collected data for sugarcane farming households in major regions of Thailand.

Birthal *et al*. (2014) studied the impact of climate change on yield of major food crops in India with its implications for food security. The study had analyzed changes in climate variables during the period for 1969-2005. Fixed effects model had been used to study its impact on yields of important food crops.

Prasert *et al.* (2014) examined the production of Thailand's sugarcane using panel data envelopment analysis based decision on bootstrapping method using collected data for sugarcane farming households in major regions of Thailand.

Kyoung-Min *et al*. (2014) attempted to explore whether or not there is an inverted-U relationship between oil consumption and economic growth. This study had employed a panel data analysis with fixed effect or random effect models using the set of data from 61 countries for the year 1990-2008.

Tokunaga *et al.* (2015) studied the impacts of climate change on agricultural production in Japan. The study had identified the impact of global warming induced climate change in Japan agricultural production. Panel data combined with time series data 1995-2006 data of eight regions of Japan had been taken to study its impact. Dynamic panel model had been used to estimate its effect.

Adhikari (2015) studied the impacts of climate variation on paddy production of Nepal. Panel data model based on Ricardian approach of climate variation was adopted for the study.

Sravanakumar (2015) studied impact of climate change on yield of major food crops in Tamil Nadu by using panel data for 39 years and 13 districts. It estimates the marginal impacts of climate variables on crop yield using Panel Corrected Standard Error(PCSE) models. The results show a quadratic (inverted U shaped) relationship between rice and sorghum yield and climate variables

Brodzicki *et al*.(2016) investigated on gravity panel data analysis of foreign trade by regions: the role of metropolises and history. The paper investigates the determinants of the intensity of foreign trade of the Polish NUTS-2 regions over 1999–2011 with an augmented panel gravity model

Damette *et al*.(2016) investigated reassessing forest products demand functions in Europe using a panel co integration approach. A partial equilibrium model of the forest sector used to simulate the implications of modified demand elasticities.

Mishra *et al*. (2017) studied the impact of climate change on pigeon pea by using district level panel data for Gujarat 1980-2011.

Alenjadaro *et al.* (2017) conducted a study on oil risk contracts, business conduct and performance patterns by using panel data analysis of the economic and financial performance data of international companies for the exploration, and exploration–extraction (E&E) of oil, as well as the patterns of institutional situation and orientation with the government market and national oil companies or NOCs that receive project offers.

Kumar (2018) examined the impact of climate change on production efficiency of rice and wheat crops in Punjab agriculture.

Baltagi *et al.* (2018) revealed the robust linear static panel data models using ε-contamination. Gaussian linear mixed model had been used with fixed effects and random effects to estimate it.

MATERIALS AND METHODS

3.1 Source of data

District wise data of Odisha for rice crop are collected from Department of Agriculture and Department of Economics and Statistics for 20 years from 1995-2015, Rajeev Bhaban, Bhubaneswar, Odisha. The data collection are of area, yield and production for paddy and also weather parameter i.e. rainfall, maximum temperature, minimum temperature. District level panel data was constructed to study the impact of weather variables on production of rice. The panel consisted of district level data on rice area, yield and production rainfall, temperature and relative humidity.

3.2 Variables used in this study are

3.2.1 Dependent variable

Rice cultivation is one of the most important agronomic crops in Odisha. The rice production kg per hectare is used as the dependent variable to study the impact of climate change.

3.2.2 Explanatory variables

3.2.2.1 Climate variables: - Rice crop is planted in Odisha by the starting time of monsoon that is in June and it is harvested around October. Hence this study covers the total rainfall; average temperature and relative humidity from planting to harvesting period of rice production i.e. total rainfall in mm. average temperature and relative humidity from January to December for each year as the climatic variables.

3.2.2.2 Temperature: - Rice production requires different temperatures at different stages from planting to harvesting. It is most important determining factor of this study which is measured in degree Celsius and taken as monthly average of twelve months from January to December. For the time and resource constraint the average temperature of 12 months of rice cultivation is calculated for the study.

3.2.2.3 Relative humidity: - It also has a great role in the production of rice. So this study has estimated its average monthly data from January to December for all districts in Odisha.

Rainfall: - Rainfall is most important factor for the rice production at its different stage. So total rainfall has been used for this study. It is measured in mm.

3.3 Methods

The statistical methods used in this study are mentioned in the following heads:

3.3.1 Study of weather parameters along all districts.
3.3.2 Study of rainfall, maximum temperature, minimum temperature and relative humidity variability of the region.
3.3.3 Econometric techniques called panel data methods are used for analysis.
3.3.4 Estimation of panel data regression models.
3.3.5 SAS software has been used for its analysis and to study its impact of climate change on production.

3.3.1 Study of weather parameters along all districts of Odisha

Climate change has a great influence in the production of rice. With ever increasing uncertainty weather change it is necessary to study the impact of climate change. The weather data has been collected for 20 years (1995-2015) for all districts in Odisha. Weather variables total rainfall in mm., average maximum temperature, average minimum temperature and average relative humidity has been collected and aggregated to form a panel data set in order to have the better efficiency of study. Odisha consist of agro-climatic zone so it is the crucial factor to observe the variation in weather parameter.

3.3.2 Study of rainfall, temperature and relative humidity characteristics of the region

In this study monthly rainfall data, temperature both maximum and minimum and relative humidity were aggregated together district wise. The descriptive statistics used to study its variability. The statistics such as mean, Standard Deviation (S.D.) and Co-efficient of Variation for monthly period were worked out as follows:

$$\bar{X} = \frac{1}{n}\sum_{x=i}^{n} X_i \sigma = \sqrt{\frac{1}{n}\sum (X_i - \bar{x}\,)^2}\; C.V. = \frac{\sigma}{\bar{X}} * 100$$

$$SE = \sigma/\sqrt{n}$$

where n= no. of months and X is the monthly data for rainfall, temperature and relative humidity.

Afterwards econometrics techniques are used for the analysis as follows:

3.3.3 Econometric technique

The econometric model specification involves regressing production per hectare against climate variables are used in rice production for the years 1995-2015 years. Panel data models examine group or individual-specific effects, time effects or both. These effects are either fixed effects or random effects. A fixed effect model examines if intercepts vary across groups or time periods, whereas a random effect model explores differences in error variance. To understand the impact of climate change on agriculture, we estimate crop production functions using panel data. To have the efficiency for the sources of potential omitted variable bias, panel data models with fixed effects is done which control the unobserved district level data that may be correlated with the explanatory variables and examine the impact of climate change on rice production. The study uses the following model:

$$y_{it} = c + \theta_i + \beta_1 T_{it} + \beta_2 R_{it} + \beta_3 P_{it} + \varepsilon_{it}$$

where

y_{it} is the production of rice in district *i* and time *t*

c is constant

θ_i are fixed effects for districts

T_{it} is the mean temperature for maximum and minimum measured in ^{o}C

R_{it} is the monthly rainfall along district i and time t measured in millimeter(mm)

P_{it} is the relative humidity

ε_{it} is the error term.

So further estimation is done by using panel data regression models as follows:

3.3.4 Estimation of panel data regression models

3.3.4.1 Fixed effects model

A fixed effects model is a statistical model in which the model parameters are fixed or non-random quantities. A fixed effects model refers to a regression model in which the group means are fixed. Data are grouped according to several observed factors along all districts of Odisha. The observed factors are rainfall, maximum temperature, minimum temperature and relative humidity. Estimation of fixed effects depends on assumptions about the intercept, the slope coefficients, and the error term. The possibilities are:

1. The intercept and slope coefficients are constant across time and districts and the error term captures differences over time and individuals.
2. The slope coefficients are constant but the intercept varies over individuals.
3. The slope coefficients are constant but the intercept varies over individuals and time.
4. All coefficients vary over individuals.
5. The intercept as well as slope coefficients vary over weather parameter and time.

Fixed effect model as follows:

Basic linear unobserved effects model for N observations and T time periods:

$y_{it} = X_{it}\beta + \alpha_i + u_{it}$ for t = 1,…., T and i=1,…,N where:

y_{it} is the dependent variable observed for individual i at time t

X_{it} is the time-variant 1*k(the number of independent variables) regressor matrix.

β is the k*1 matrix of parameters.

α_i is the unobserved time-invariant individual effect

u_{it} is the error term.

The study has used this model as follows:

$$\ln y_{it} = D_i + T_i + \beta_1 X_{it} + \beta_2 P_{it} + \varepsilon_{it}$$

y_{it} is the production of rice along district i and time t.

$D_i$represents district fixed effects. It absorbed all the unobserved district specific time-invariant factors and also reduces bias due to omitted variables.

T_i is the time fixed effects controlling the differences in crop production which could be due variation in weather parameters.

X_{it} is a vector of weather variables. The effect of rainfall and temperature is not linear so average maximum and minimum temperature along with total rainfall has been taken.

P_{it} is the relative humidity along districts i and time t.

3.3.4.2 Random effects model

This model is also known as variance components model and is a kind of hierarchical linear model. It assumes that the data being analyzed are drawn from a hierarchy of different populations whose differences related to that hierarchy. It is a special case of fixed effects model where fixed effects are not assumed. This model has also assumptions

1. The individual specific effects are uncorrelated with the independent variables. It is studied in order to check its consistency, if the assumption does not holds good, the model is not consistent.

The basic formula as follows:

$$Y_{it} = \beta_{1i} + \beta_2 X_{2it} + \beta_3 X_{3it} + \varepsilon_i + \upsilon_{it}$$

Here in this above equation β_{1i} is not treated as fixed and it is assumed as random variable with a mean value of β_1. And the intercept value for an individual can be expressed as

$\beta_{1i} = \beta_1 + \varepsilon_i$ Where i=1, 2… N where ε_i is a random error term with a mean value of zero and variance$\sigma_\varepsilon{}^2$.

For the specification of model, Hausman test is to be done for comparing between random effects model and fixed effects model as follows:

3.3.4.3 Durbin-Wu-Hausman Test

The Durbin-Wu-Hausman test is a statistical hypothesis test which evaluates the consistency of an estimator when compared to an alternative. It helps to evaluate if a statistical model corresponds to the data.

Wu-Hausmann statistic is

$$H = (b_1 - b_0)'(Var(b_0) - Var(b_1)) +$$

where + denotes the Moore-Penrose pseudo inverse. Under the null hypothesis, the statistic has asymptotically the chi-squared distribution with the number of degrees of freedom equal to the rank of matrix$Var(b_0) - Var(b_1)$. Hence to differentiate between fixed effects model and random effects model, Random effects model is preferred under the null hypothesis due to higher efficiency, while under the alternative fixed effects is at least as consistent and preferred. The following table will represent its estimator:

Hausmann test

	H_0 is true	**H_1 is true**
b_1 (RE estimator)	Consistent Efficient	Inconsistent
b_0 (FE estimator)	Consistent Inefficient	Consistent

3.3.4.4 Pooled (OLS) estimator

This estimator allows pooling time series cross sectional data and running regression on the data. It helps in analysis and also compares model across time and access to HCCME (Heteroscedastic consistent covariance matrix). The model is as follows:

$$y_{it} = \alpha + \beta' X_{it} + u_{it} \ ,$$

i=1,…., N, t=1,…, T. Assume there are K regressors (Covariates), such that dim(β)=K. Panel models mainly differ in their assumptions on *u*. *u* independent across I and t, E*u*=0, and var u=σ^2 define the pooled regression model. It is efficiently estimated by least squares (OLS).

RESULTS

The results of this study have been presented over here in a tabular form keeping in view with the objective of the study.

4.1 To study the variability of weather parameters.

4.2 To study the impact of the change in weather variables on rice in Odisha.

4.1.1 Estimation of yearly rainfall, maximum temperature, minimum temperature and relative humidity per annum along districts statistics

Odisha agriculture mostly depends on monsoon rains. As rice is staple food crop in Odisha, it contributes more to the agricultural land. The rice crop requires hot and humid climatic conditions for its successful cultivation. Rice crop is suited for the regions where abundant water supply or maximum rainfall, high humid and prolonged sunshine is available. Hence the amount of rainfall has a great significance towards the production of rice and to observe its variation along districts is the crucial factor to measure its pattern. The average maximum temperature and average minimum temperature is also required for the cultivation of rice crop. Hence to study its year to year variation along all districts is necessary for the observation in production of crop. The relative humidity has also a great role towards the cultivation of crop, so it has significant importance to study its year to year variation along with districts of Odisha. For this study the secondary data have been collected for monthly rainfall data for 20 years (1995-2015) along with average maximum temperature, average minimum temperature and relative humidity. Descriptive statistics have been calculated to know the variability in weather parameters. For different weather variables the mean, standard deviation and coefficient of variation have been calculated to know the variability within the districts of Odisha.

Table: 4.1.1.1 Yearly average of rainfall for districts of Odisha (1995-2015)

District name	Mean	SD	CV
Balasore	1655.65	354.69	21.42
Bhadrak	1476.28	323.80	21.93
Bolangir	1239.66	310.01	25.01
Sonepur	1332.27	321.04	24.10
Cuttack	1508.98	353.01	23.39
Jagatsinghpur	1407.94	316.06	22.45
Jajpur	1520.98	312.77	20.56
Kendrapara	1460.36	345.03	23.63
Dhenkanal	1379.66	247.18	17.92
Angul	1355.75	302.51	22.31
Ganjam	1289.46	287.47	22.29
Gajapati	1333.49	248.82	18.66
Kalahandi	1558.29	404.13	25.93
Nuapada	1119.70	249.15	22.25
Keonjhar	1416.32	300.56	21.22
Koraput	1441.20	223.90	15.54
Malkangiri	1495.68	272.95	18.25
Nowrangpur	1566.79	354.89	22.65
Rayagada	1278.45	288.86	22.59
Mayurbhanj	1534.69	272.96	17.79
Phulbani	1640.46	310.23	18.91
Boudh	1354.49	362.59	26.77
Puri	1479.37	369.48	24.98
Khurda	1452.44	320.70	22.08
Nayagarh	1396.27	273.65	19.60
Sambalpur	1447.80	337.67	23.32
Bargarh	1269.62	251.58	19.82
Deogarh	1316.83	259.61	19.71
Jharsuguda	1305.30	305.05	23.37
Sundergarh	1310.08	205.53	15.69

Table 4.1.1.1 reveals that Balasore has the highest rainfall with mean of 1655.55 mm followed by Phulbani with the mean rainfall of 1640.46mm. The least annual rainfall is of Nuapada district with the mean rainfall of 1119.70 mm. Table clearly shows that highest rainfall mostly occurs in eastern Odisha as it consists of coastal districts. Kalahandi district is the only district showing highest rainfall among western Odisha. Western Odisha have lowest rainfall region which except Bargarh district which accounts for highest production of 12834 tones. The coefficient of variation due to yearly rainfall ranges from 15.54% (lowest) to 25.1% (highest). The most reliable districts are Sundergarh, Mayurbhanj, Malkangiri, Gajapati, Phulbani, Bargarh, Deogarh as they show coefficient of variation values of 15.69, 17.79, 18.25, 18.66, 18.91, 19.82, 19.71 respectively. The coefficient of variation values of Bolangir, Sambalpur, Jharsuguda, Nowrangpur, Nuapada, Rayagada were higher. The overall rainfall is quite lower for these districts.

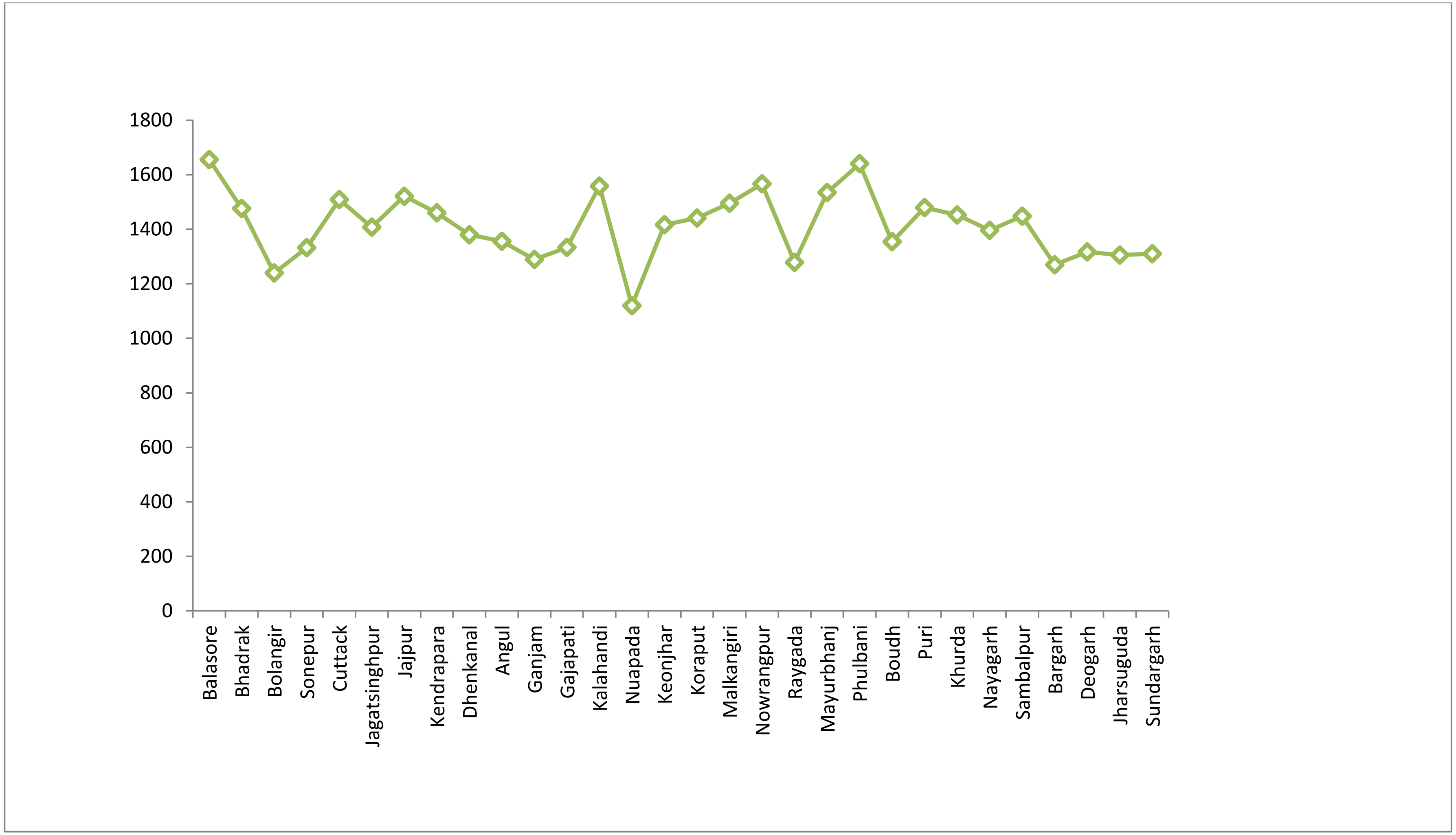

Figure 4.1.1.1Rainfall distribution among all districts of Odisha

Table 4.1.1.2 Average maximum temperature for districts of Odisha (1995-2015)

District name	MEAN	SD	CV
Balasore	31.85	0.60	1.88
Bhadrak	32.12	2.42	7.52
Bolangir	33.36	2.86	8.57
Cuttack	32.67	0.94	2.89
Jagatsinghpur	31.05	1.36	4.39
Dhenkanal	32.21	1.17	3.64
Angul	33.19	1.17	3.52
Ganjam	31.13	0.41	1.32
Kalahandi	31.69	5.81	18.33
Keonjhar	30.93	0.55	1.77
Koraput	30.56	2.32	7.59
Malkangiri	32.49	1.11	3.43
Mayurbhanj	31.57	1.15	3.65
Phulbani	31.77	2.11	6.65
Puri	31.02	0.50	1.60
Khurda	33.21	0.58	1.74
Sambalpur	32.87	2.45	7.45
Bargarh	32.06	1.48	4.61
Jharsuguda	33.15	0.73	2.21
Sundergarh	33.15	2.62	7.91

Table 4.1.1.2 reveals that Bolangir has the highest mean maximum temperature with 33.36^{o}C followed by Khurda with 33.21^{o}C. The lowest maximum temperature is of Puri district with the mean maximum temperature of 31.02^{o}C. It has shown that maximum temperature is highest towards western and eastern Odisha of Bolangir, Angul, Khurda, Bargarh, Dhenkanal, Cuttack, and Bhadrak. The standard deviation varies from 0.50 (lowest) to 5.81(highest). The coefficient of variation ranges from 1.32 %(lowest) to 18.33 %(highest).

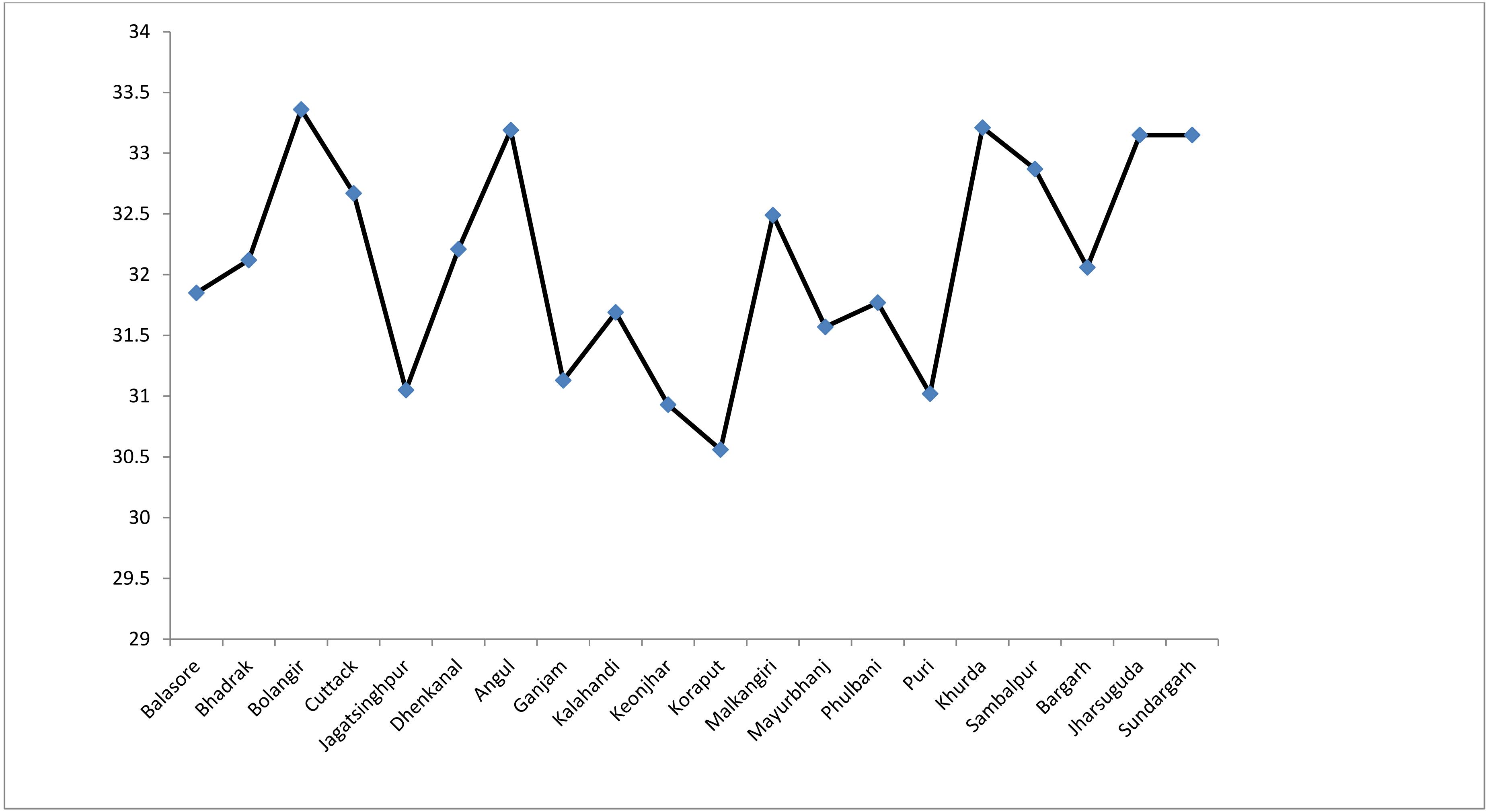

Figure 4.1.1.2 Average maximum temperature for the districts of Odisha

Table 4.1.1.3 Average Minimum temperature of districts of Odisha (1995-2015)

District Name	Mean	SD	CV
Balasore	22.08	0.56	2.52
Bhadrak	22.16	0.92	4.16
Bolangir	20.64	2.99	14.49
Cuttack	21.04	1.76	8.39
Jagatsinghpur	23.28	1.14	4.90
Dhenkanal	23.60	1.67	7.06
Angul	19.90	1.77	8.92
Ganjam	23.31	0.64	2.73
Kalahandi	19.40	1.68	8.65
Keonjhar	19.48	1.55	7.95
Koraput	17.35	1.97	11.36
Malkangiri	17.58	1.07	6.09
Mayurbhanj	20.38	2.13	10.47
Phulbani	17.75	2.71	15.25
Puri	24.10	1.06	4.39
Khurda	22.67	0.91	4.01
Sambalpur	20.67	3.48	16.85
Bargarh	20.28	0.82	4.03
Jharsuguda	20.96	0.54	2.56
Sundergarh	18.44	2.39	12.98

Table 4.1.1.3 reveals that Puri has the highest average minimum temperature with mean temperature of 24.10^{o}C followed by Dhenkanal having mean temperature of 23.60^{o}C. Koraput has lowest average minimum temperature among all districts with the mean of 17.35^{o}C. The standard deviation ranges as 0.56 to 2.99 which reveals that there is a smaller variation among districts. The coefficient of variation ranges from 2.52 % (lowest) to 16.85% (highest). The districts having low coefficient of variation are Jharsuguda, Ganjam, Balasore, Puri, Khurda, Bhadrak with 2.56%, 2.73%, 2.52%, 4.39%, 4.01%, 4.16%. This shows reliability towards average minimum temperature. In this table it has also shown that eastern Odisha has more reliability towards average minimum temperature.

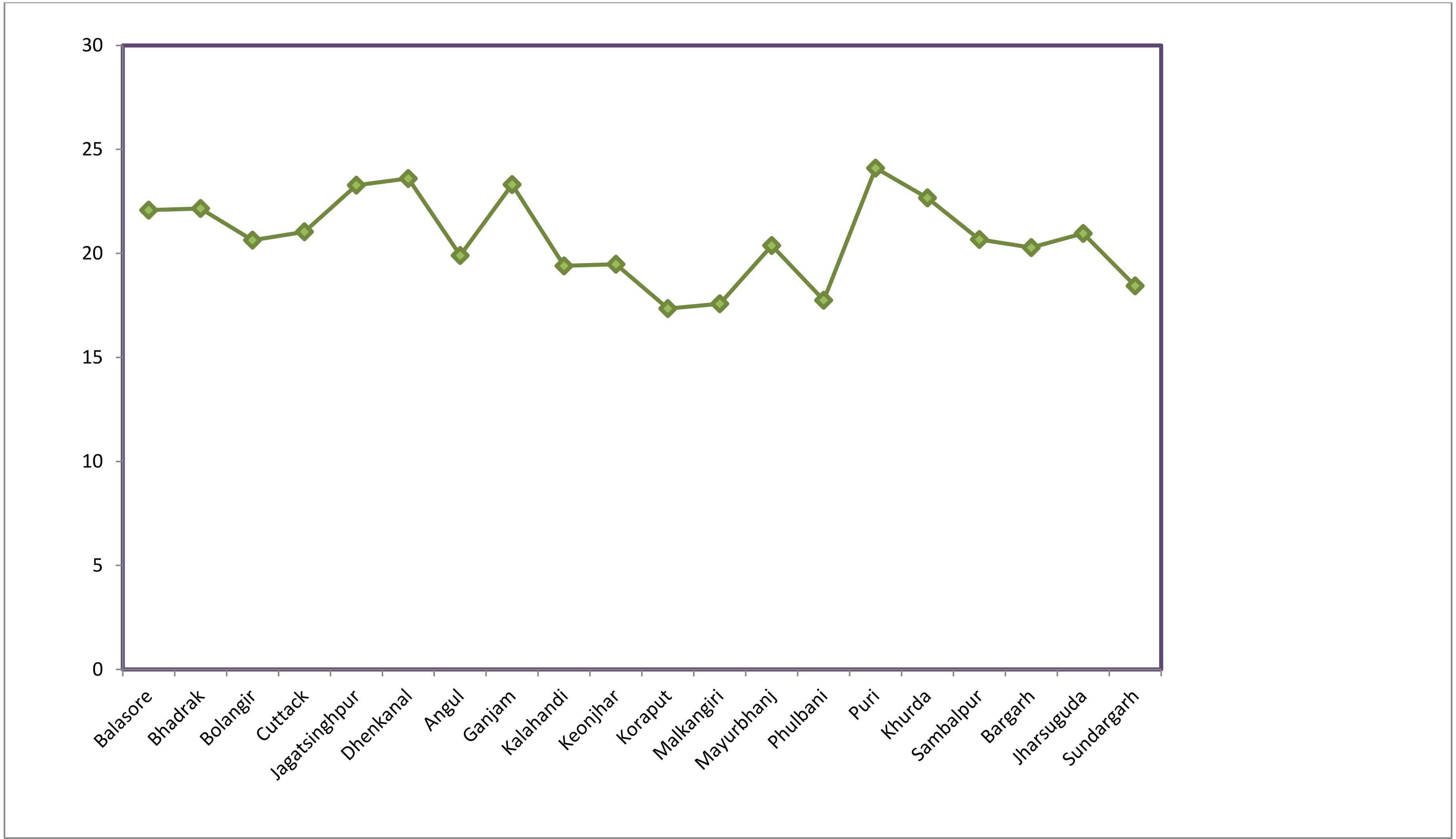

Figure 4.1.1.3 Average minimum temperatures for the districts of Odisha

Table 4.1.1.4 Average relative humidity for all districts of Odisha (1995-2015)

Sl. No.	District name	Mean	SD	CV
1	Balasore	70.60	4.12	5.83
2	Bhadrak	78.75	7.00	8.89
3	Bolangir	67.69	7.95	11.75
4	Cuttack	79.68	5.71	7.16
5	Jagatsinghpur	80.41	4.16	5.17
6	Dhenkanal	74.68	1.80	2.40
7	Angul	72.69	6.46	8.88
8	Ganjam	81.65	2.45	3.00
9	Kalahandi	69.25	7.46	10.77
10	Keonjhar	70.47	4.58	6.50
11	Koraput	74.73	9.57	12.81
12	Malkangiri	73.73	13.90	18.86
13	Mayurbhanj	77.57	5.61	7.23
14	Phulbani	79.61	6.02	7.57
15	Puri	79.81	5.39	6.76
16	Khurda	79.07	2.24	2.83
17	Sambalpur	74.56	3.60	4.83
18	Bargarh	75.24	1.44	1.91
19	Jharsuguda	68.43	2.88	4.21
20	Sundergarh	69.10	7.44	10.77

Table 4.1.1.4 reveals that Ganjam has highest relative humidity with the mean relative humidity of 81.65% followed by Jagatsinghpur with the mean relative humidity of 80.41%. Bolangir has shown the lowest relative humidity with the mean relative humidity of 67.69%. The standard deviation ranges from 1.44 (lowest) to 13.90 (highest), Bargarh shows lowest standard deviation and Malkangiri 13.90 highest standard deviation. The eastern Odisha has shown it variation in relative humidity. The coefficient of variation is lowest for Bargarh district (1.91%) and the highest is for Malkangiri (18.86%).

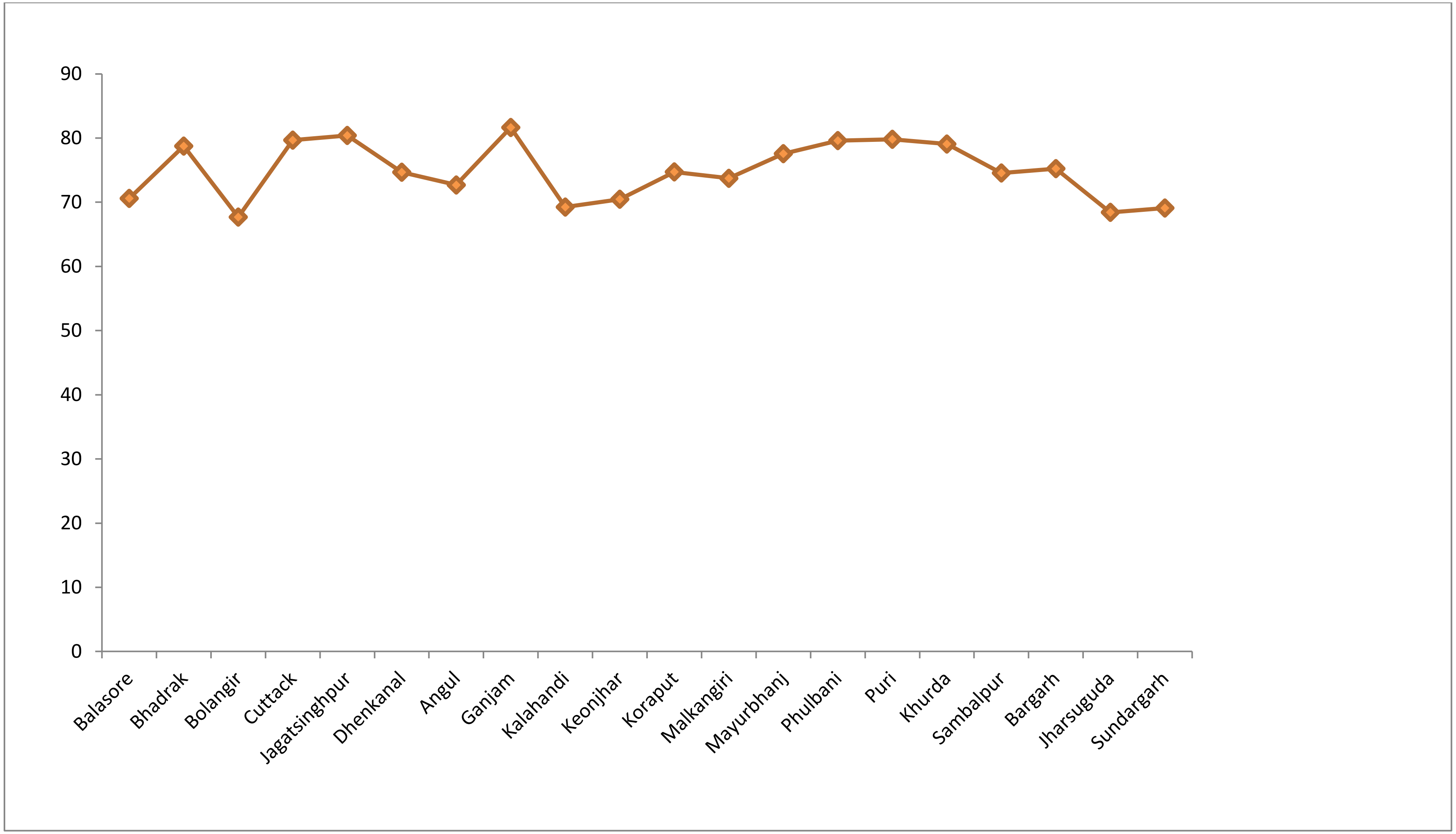

Figure 4.1.1.4 Average relative humidity for the districts of Odisha

4.2 Estimation of impact of change in weather variables on rice in Odisha.

To study the impact of change in weather variables panel data models have been used. Pooled OLS estimator, between group estimates, fixed effects model, random effects model, Parks method and Da Silva method are used to study the impact of climate change. The estimation for different panel data model is shown in a tabular form as follows:

4.2.1 Pooled (OLS) estimates

The estimation as follows:

4.2.1.1 Table for fitting model

Fit Statistics					
MSE	93092.9	Root MSE	305.1	R-Square	0.01

Table 4.2.1.1 for fitting the model shows that R-square value is 0.01 which is a poor fit.

4.2.1.2 Table for parameter estimation

Parameter estimate				
Variable	DF	Estimate	Standard Error	Pr > |t|
Intercept	1	449.26	303.1	0.14
Rainfall	1	0.02	0.02	0.33
Maximum temperature	1	0.78	6.92	0.91
Minimum temperature	1	5.15	5.48	0.35
Relative humidity	1	-5.32	2.02	0.008

Table 4.2.1.2 shows the estimation of each parameter where rainfall, maximum temperature and minimum temperature are not significant. Whereas, relative humidity is highly significant and the estimate is negative so it contributes negatively to production. This method reveals that rainfall, maximum temperature and minimum temperature are not significant which concludes that they don’t contribute towards the production. The relative humidity is significant hence it has contribution towards production but as the estimate is negative it shows with the increase or decrease of relative humidity may affect production.

4.2.2 Between group estimates

The estimation as follows:

4.2.2.1 Table for fitting model

Fit Statistics					
MSE	2232.62	Root MSE	47.25	R-Square	0.6

Table 4.2.2.1 for fitting the model shows that R-square value is 0.6 which is in the range from 0 to 1, and it concludes that it fits the model.

4.2.2.2 Table for parameter estimate

Parameter estimate				
Variable	**DF**	**Estimate**	**Standard Error**	**Pr > |t|**
Intercept	1	235.60	712.0	0.74
Rainfall	1	0.03	0.05	0.57
Maximum temperature	1	-49.65	19.78	0.02
Minimum temperature	1	63.29	13.97	0.00
Relative humidity	1	2.922	4.93	0.56

Table 4.2.2.2 shows the estimation of each parameter where rainfall and relative humidity are not significant. The maximum temperature and minimum temperature are significant. This method reveals that the rainfall and relative humidity doesn’t contribute towards production. But the maximum temperature and minimum temperature are significant hence it reveals that both contribute towards the production. The minimum temperature estimate value is 63.29^{o}C which reveals that higher the minimum temperature more is the production but the maximum temperature estimate is negative which concludes that it may affect the production.

4.2.3 Fixed one way estimates

The estimation is as follows:

4.2.3.1 Table for fitting model

Fit Statistics					
MSE	93299.18	Root MSE	305.45	R-Square	0.06

Table 4.2.3.1 for fitting the model shows that R-square value is 0.06 which is a poor fit.

4.2.3.2 F-test

F-test for no fixed effects			
Num DF	**Den DF**	**F Value**	**Pr > F**
20	395	0.95	0.52

Table 4.2.3.2 reveals F-test to study the null hypothesis in the model whether fixed effects are zero or non-zero. Table represents that null hypothesis is rejected so the test is for fixed effects and it is non-zero.

4.2.3.3 Table for Parameter estimate

Parameter estimate				
Variable	**DF**	**Estimate**	**Standard Error**	**Pr > |t|**
CS1	1	-195.6	102.3	0.056
CS2	1	-262.1	99.9	0.0090
CS3	1	-238.4	100.8	0.018
CS4	1	-275.0	98.9	0.005
CS5	1	-259.0	101.2	0.010
CS6	1	-273.3	100.9	0.0070
CS7	1	-227.9	101.4	0.02
CS8	1	-323.3	100.0	0.001
CS9	1	-235.5	100.2	0.01
CS10	1	-234	99.9	0.01
CS11	1	-228.6	99.8	0.02
CS12	1	-244.1	99.2	0.01
CS13	1	-203.3	99.9	0.04

CS14	1	-213.5	100.9	0.03
CS15	1	-202.8	100.1	0.04
CS16	1	-190.3	99.9	0.05
CS17	1	-271.1	102.3	0.008
CS18	1	-129.9	100.6	0.20
CS19	1	-183	102.1	0.07
CS20	1	-116.5	100.7	0.25
Intercept	1	607	317.8	0.05
Rainfall	1	0.02	0.03	0.46
Maximum temperature	1	3.98	7.25	0.58
Minimum temperature	1	0.39	5.82	0.95
RH	1	-4.51	2.17	0.04

Table 4.2.3.3 shows for the fixed one-way effects where CS 2 to CS 17 and CS 19 are significant whereas CS 1, CS 18 and CS 20 are not significant. And the weather parameter relative humidity has shown significance and rainfall, maximum temperature and minimum temperature are not significant. This method has reveal that relative humidity has significance contribution towards production, as its estimate is -4.51 it concludes that with the increase or decrease of relative humidity may affect production. The other weather parameters i.e. rainfall, maximum temperature and minimum temperature has shown no significant difference and it concludes that with the increase and decrease of these parameters may not affect production.

4.2.4 Fuller and Battese Variance Components (Ran One)

This is for the random one way effects and it is also called as Fuller and Battese variance components. The estimation is as follows:

4.2.4.1 Table for fitting model

Fit statistics					
MSE	92843.7	Root MSE	304.7	R-Square	0.01

Table 4.2.4.1 for fitting the model shows that R-square value is 0.01 which is a poor fit.

4.2.4.2 Variance components estimates

Variance Component Estimates	
Variance Component for Cross Sections	302.8
Variance Component for Error	93299.1

4.2.4.3 Hausman test

Hausman Test for Random Effects		
DF	**m Value**	**Pr > m**
4	9.87	0.04

Table 4.2.4.3 shows Hausmann test for random effects which is done to check null hypothesis is accepted or rejected. Table clearly shows that null hypothesis is rejected and no random effects.

Table 4.2.4.4 Table for Estimate of parameter

Parameter Estimate				
Variable	**DF**	**Estimate**	**Standard Error**	**Pr > |t|**
Intercept	1	446.72	303.6	0.14
Rainfall	1	0.02	0.03	0.33
Max temperature	1	0.95	6.94	0.89
Min temperature	1	4.89	5.49	0.37
RH	1	-5.28	2.02	0.009

Table 4.2.4.4 shows the estimation of each parameter where rainfall, maximum temperature and minimum temperature are not significant. Whereas, relative humidity is highly significant and the estimate is negative so it contributes negatively to production. This method reveals that rainfall, maximum temperature and minimum temperature are not significant which concludes that they don't contribute towards the production. The relative humidity is significant hence it has contribution towards production but as the estimate is negative it shows with the increase or decrease of relative humidity may affect production.

4.2.5 Fuller and Battese Variance Components (Ran Two)

The estimation is for random two way effects and the results of estimation are as follows:

4.2.5.1 Table for fitting the model

Fit Statistics					
MSE	83784.1	Root MSE	289.4	R-Square	0.01

Table 4.2.5.1 for fitting the model shows that R-square value is 0.01 which is a poor fit.

4.2.5.2 Variance components estimates

Variance Component Estimates	
Variance Component for Cross Sections	1052.8
Variance Component for Time Series	9803.5
Variance Component for Error	83955.7

4.2.5.3 Hausman test

Hausman Test		
DF	**m Value**	**Pr > m**
4	10.82	0.0286

Table 4.2.5.3 shows Hausman test that is the test for hypothesis and it reveals that null hypothesis is accepted or rejected. And the null hypothesis that the effect is random effects and the table shows that null hypothesis is rejected.

4.2.5.4 Table for parameter estimate

Parameter estimate				
Variable	**DF**	**Estimate**	**Standard Error**	**Pr > |t|**
Intercept	1	568.26	321.5	0.07
Rainfall	1	0.009	0.02	0.74
Maximum temperature	1	-0.50	7.00	0.94
Minimum temperature	1	0.17	6.43	0.97
RH	1	-4.59	2.20	0.03

Table 4.2.5.4 shows the estimation of each parameter where rainfall, maximum temperature and minimum temperature are not significant. Whereas, relative humidity is highly significant and the estimate is negative so it contributes negatively to production. This method reveals that rainfall, maximum temperature and minimum temperature are not significant which concludes that they don't contribute towards the production. The relative humidity is significant hence it has contribution towards production but as the estimate is negative it shows with the increase or decrease of relative humidity may affect production.

4.2.6 Fixed two way estimates

The fixed effect model in two way estimates as follows:

4.2.6.1 Table for fitting the model

Fit Statistics					
MSE	83955.7	Root MSE	289.7	R-Square	0.2

Table 4.2.6.1 for fitting the model shows that R-square value is 0.2 which is not a good fit.

4.2.6.2 F-test

F Test for No Fixed Effects			
Num DF	**Den DF**	**F Value**	**Pr > F**
39	376	2.16	0.0001

Table 4.2.6.2 reveals F-test to study the null hypothesis in the model whether fixed effects are zero or non-zero. Table represents that null hypothesis is rejected so the test is for fixed effects and it is non-zero.

4.2.6.3 Parameter Estimates

Parameter estimate				
Variable	**DF**	**Estimate**	**Standard Error**	**Pr > |t|**
CS1	1	-233.59	99.31	0.0192
CS2	1	-308.83	96.46	0.0015
CS3	1	-267.63	97.15	0.0062
CS4	1	-308.44	95.14	0.0013
CS5	1	-300.42	97.93	0.0023
CS6	1	-325.88	97.91	0.0010
CS7	1	-255.48	97.68	0.0093
CS8	1	-347.37	95.70	0.0003
CS9	1	-247.75	95.93	0.0102
CS10	1	-274.37	96.71	0.0048
CS11	1	-252.65	95.95	0.0088
CS12	1	-257.64	95.15	0.0071
CS13	1	-227.22	96.13	0.0186
CS14	1	-238.17	97.09	0.0146
CS15	1	-223.31	95.90	0.0204
CS16	1	-213.94	95.80	0.0261
CS17	1	-301.08	98.98	0.0025
CS18	1	-150.89	96.63	0.1192
CS19	1	-210.83	98.63	0.0332
CS20	1	-137.95	96.81	0.1550
TS1	1	-180.93	94.55	0.0564
TS2	1	-197.18	97.34	0.0435
TS3	1	-293.13	91.16	0.0014
TS4	1	-294.16	95.98	0.0023

TS5	1	-265.27	102.0	0.0097
TS6	1	-79.78	99.33	0.4224
TS7	1	-439.46	90.78	<.0001
TS8	1	-94.38	102.9	0.3594
TS9	1	-284.38	90.41	0.0018
TS10	1	-394.35	91.33	<.0001
TS11	1	-308.82	92.49	0.0009
TS12	1	-421.63	90.39	<.0001
TS13	1	-371.29	93.73	<.0001
TS14	1	-300.88	94.02	0.0015
TS15	1	-289.79	104.2	0.0057
TS16	1	-212.22	98.60	0.0320
TS17	1	-399.73	92.35	<.0001
TS18	1	-389.70	92.33	<.0001
TS19	1	-183.73	91.60	0.0456
Intercept	1	1209.21	356.4	0.0008
Rainfall	1	-0.006	0.03	0.8555
Max temperature	1	1.68	7.47	0.8224
Min temperature	1	-11.73	7.84	0.1348
RH	1	-3.63	2.56	0.1566

Table 4.2.6.3 shows the estimation of parameter including both cross-sectional effects and time series effect for fixed two way model. Most of the cross sectional effects are highly significant excluding CS18 and CS20. This means that cross sections are significantly different from 21st cross section. Many of the time series shows significant effect, but this is not uniform. It shows that significance might be driven by a large 20th period effect, since the first six time effects are negative and of similar magnitude. The weather parameter rainfall, maximum temperature, minimum temperature and relative humidity show not significant. This method has shown that the weather parameter doesn’t contribute towards production.

4.2.7 Parks Method

This method attempts to estimate first-order autocorrelation coefficients for each cross section. It is also called as Feasible generalized least squares. The following results estimate:

4.2.7.1 Table for fitting the model

Fit statistics					
MSE	0.692	Root MSE	0.832	R-Square	0.863

Table 4.2.7.1 for fitting the model shows that R-square value is 0.8 which is in the range from 0 to 1 and it concludes that it fits the model. The model reveals for the accuracy as the value of R-square value is nearer to 1.

4.2.7.2 Table for Parameter estimation

Parameter Estimate				
Variable	**DF**	**Estimate**	**Standard Error**	**Pr > |t|**
Intercept	1	370.45	20.37	<.0001
Rainfall	1	0.02	0.002	<.0001
Max temperature	1	3.28	0.46	<.0001
Min temperature	1	5.37	0.36	<.0001
RH	1	-5.22	0.15	<.0001

Table 4.2.7.2 shows the estimation of parameter. The parameter rainfall, maximum temperature, minimum temperature and relative humidity shows significance. It completely defines that there is a significant difference among rainfall, maximum temperature, minimum temperature and relative humidity. With the rise or fall of these weather parameters can affect the production of crop. The estimate of relative humidity is – 5.22 which is negative, so it concludes that it contributes negatively on production and with the fall of it humidity conditions its affect the production of crop.

4.2.8 Da- Silva Method

TheDa Silva method is also called variance component moving average model. It assumes that the observed value of the dependent variable at the t- time period on the i-cross sectional unit. The estimation for this method is as follows:

4.2.8.1 Table for fitting the model

Fit Statistics					
MSE	0.99	Root MSE	0.99	R-Square	0.01

Table 4.2.8.1 for fitting the model shows that R-square value is 0.01 which is a poor fit.

4.2.8.2 Variance components estimates

Variance Component Estimates	
Variance Component for Cross Sections	0
Variance Component for Time Series	8980.03

Table 4.2.8.3 Table for parameter estimate

Parameter Estimate				
Variable	**DF**	**Estimate**	**Standard Error**	**Pr > |t|**
Intercept	1	554.97	319.0	0.08
Rainfall	1	0.01	0.02	0.73
Max temperature	1	-0.20	6.99	0.98
Min temperature	1	1.52	6.35	0.81
RH	1	-4.93	2.18	0.02

Table 4.2.8.3 shows the estimation of weather parameter. Here also like other methods relative humidity is significant. The other parameter rainfall, max temperature and min. temperature shows no significant effect. As the estimate of relative humidity shows a negative value of -4.93, it reveals that with the decrease in the level of relative humidity can cause effect on the production of crop. This method has shows that rainfall, maximum temperature and minimum temperature don’t have any effect on the production.

DISCUSSION

After the analysis of data and getting the results here deals with the predetermined part of study i.e. discussion. The discussion should be on the terms of following heads:

4.1 Discussion of variability of weather parameter of all districts in Odisha

4.2 Discussion of the econometric techniques used to analyze the data and to aggregate to form a panel data

4.3 Discussion of different panel data models which is used to estimate the impact of climate change on rice in Odisha using Panel data.

4.1 Discussion of variability of weather parameters of all districts in Odisha

Climate is the most influential character for the agricultural production in Odisha. With the ever increasing temperature that imposing a threat towards the production of crop, it is crucial factor to study its effects on rice production. Odisha lies in the subtropical belt in India and hence it covers a tropical and subtropical region. The data has been collected for 20 years of all districts to check its variability, weather parameters like rainfall, average maximum temperature, minimum temperature and relative humidity has been collected. To check the variability descriptive statistics i.e. mean, standard deviation and coefficient of variation have been used to estimate its variability in all districts. The western districts of Odisha i.e. Sundergarh, Sambalpur, Bargarh, Bolangir, Kalahandi and Mayurbhanj are warm almost throughout the year with the mean maximum temperature ranges between 35-40^{o} C and the mean minimum temperature ranges between 20-25^{o} C. Winter is not very severe except in some areas in Koraput and Phulbani where minimum temperature may drop to 3-4 ^{o}C. The study has shown that districts mean maximum temperature is highest in the western Odisha and mean minimum temperature is lowest in eastern Odisha which tends to affect the production of rice in eastern districts and quite higher in western district in Bargarh with the production of 12834.73 tones. The study has revealed that the western districts and eastern districts have shown its variability. The mean yearly rainfall is highest in Balasore district with the mean rainfall of 1655.65mm of northern side followed by Phulbani district 1640.46mm. Nuapada district has the lowest rainfall of mean 1119.7mm. Rainfall pattern in northern districts have highest mean followed by western district which has shown the lowest rainfall mean. Relative humidity has shown the highest in Ganjam district of eastern Odisha followed by Jagatsinghpur district.

4.2 Discussion of the econometric techniques used to analyses the data and to aggregate to form a panel data

Econometric techniques have been used to study the impact of climate change. The data collected for 20 years has been collected to aggregate to form a panel data set as it enhances to study both for time series effect and cross sectional effects. The techniques used in panel data is by combining time series of cross section observations and makes data more informative, more variability, less collinearity among variables, more degrees of freedom that enhances more efficiency. Panel data can better detect and measure effects that cannot be observed in pure cross section or time series data. Hence 20 years data have been collected for all districts of Odisha from 1995-2015. Data are aggregated in the form of both time series and cross sectional in order to have the better efficiency of the analysis.

4.3 Discussion of different panel data models which is used to estimate the impact of climate change on rice in Odisha using Panel data.

Various models have been used to estimate the impact of climate change on rice in Odisha. The study uses pooled effect model, fixed effect model, random effects model, Da Silva method and Parks method. In pooled effect model, the estimator allows to pool time series cross sectional data and run regression on the data. The estimate of pooled effect model has shown that total rainfall, average maximum temperature and average minimum temperature are not significant whereas relative humidity is significant. As the relative humidity has a negative value it concludes that with the increase and decrease of the humidity that may affect the production of crop. The fixed effect model is the statistical model in which the model is fixed or nonrandom quantities. Fixed effects model has shown that rainfall, maximum temperature and minimum temperature are not significant, but relative humidity has significant effect. Fixed effect model has concluded that the rainfall, maximum temperature and minimum temperature don't contribute towards production. The relative humidity has negative value -4.51 conclude that with the rise and fall of humidity may affect the production. The random effects model is a variance component model, it assumes that the data being analyzed are drawn from hierarchy of different districts. Random effects model had concluded that rainfall, maximum temperature and minimum temperature has no effect on production. The relative humidity contributes negatively towards the production of crop. Parks Method has shown significance for all weather parameter i.e. rainfall, maximum temperature, minimum temperature and relative humidity. The method has concluded that rainfall, maximum temperature, minimum temperature and relative humidity it contributes towards the production of the crop. With the increase and decrease of the weather parameter contributes towards the production of rice. The slight fluctuation in the weather parameter may leads towards the destruction in production of crop. Da Silva method has shown that rainfall, maximum temperature and minimum temperature are not significant, but relative humidity has shown significant effect. As the estimate of relative humidity shows a negative value of -4.93, it reveals that with the decrease in the level of relative humidity can cause effect on the production of crop. This method has shown that rainfall, maximum temperature and minimum temperature don’t have any effect on the production. Hausmann test is the null hypothesis test which is done to differentiate between random effects model and fixed effects model and it had kept null hypothesis for random effects model and alternative for fixed effects model. As it rejects null hypothesis for random effects model, so alternative hypothesis fixed effect model is preferred. Hence fixed effects model is appropriate to study the impact of climate change. As far as concerned the weather parameters i.e. rainfall, maximum temperature, minimum temperature and relative humidity contributes towards the production of crop. The comparison between all panel models, Parks method has shown significant effect in all the weather parameters. Hence it concludes that parks method is appropriate method to study the impact of climate change on the production. The study had shown that there is a variation in rainfall, average maximum and minimum temperature and relative humidity and had great impact on the production of rice. With the scarcity of rainfall may affect production. Rice crop can tolerate maximum temperature up to 42^{o}C and cooler temperature is not preferable, hence with the increase in maximum temperature may affect production and with the decrease in the minimum temperature may drastically affect the production of crop. The relative humidity has also shown significant effect towards production and the fluctuation in the relative humidity affects production.

SUMMARY

The chapter 1 gives an overall idea about panel data methods and its different application and the climatologically pattern of Odisha and the importance of weather parameters to the cropping pattern in Odisha. The panel data models had been used to study the behavior of climate variables on the production of rice. Statistical models for the analysis of panel data is a rapidly growing field of methodological inquiry, so this panel data model has been taken into consideration to study the impact of climate change on rice. The data for the year 1995-2015 had been collected for area, yield, production and weather parameters total rainfall and average maximum temperature, average minimum temperature and relative humidity for all 30 districts of Odisha.

Keeping in view the importance of weather variables in Odisha on the production of rice an attempt was taken to study the impact of climate on rice. For this purpose, the data for all the districts of Odisha had been taken into consideration by collecting the data for the area, yield and production from Directorate of Agriculture and Directorate of Economics and Statistics, Rajeev Bhaban, Bhubaneswar. The present study on "Statistical investigation on the impact of climate change on rice in Odisha using Panel data" primarily aims in estimating the weather variability in different districts of Odisha and different panel data models had been used to study the impact of the change in weather variables on rice in Odisha. The calculation by using descriptive statistics i.e. mean, standard deviation and coefficient of variation had been used to study the variability in weather parameters. The panel data models used for the analysis are Pooled model, Fixed effects model, and Random effects model.

The salient features of the study are as follows:

1. The mean annual rainfall of the region was found to be 1141.47 mm. Balasore has the highest rainfall with the mean of 1655.55 mm followed by Phulbani with the mean rainfall of 1640.46mm. The least annual rainfall is of Nuapada district with the mean rainfall of 1119.70 mm. The highest rainfall mostly occurs in eastern Odisha as it consists of coastal districts. Kalahandi district is the only district showing highest rainfall among western Odisha. Western Odisha has medium rainfall region except for Bargarh district which accounts for the highest production of 12834 tonnes. Though Bargarh has medium rainfall for rice production still this district gives the highest

production due to highest area coverage on rice and most of the people in that district are engaged in agricultural activities. This Bargarh district is considered as ‘Rice bowl of Odisha’.

2. The maximum temperature ranges between 31-40°C where Bolangir district has the highest mean maximum temperature with 33.36°C followed by Khurda with 33.21°C. The lowest maximum temperature is of Puri district with the mean maximum temperature of 31.02°C. The highest average minimum temperature is of Puri district of 24.10°C followed by Dhenkanal having the mean temperature of 23.60°C. Koraput has the lowest average minimum temperature among all the districts with the mean of 17.35°C. It has shown that maximum temperature is highest towards the western and eastern Odisha of Bolangir, Angul, Khurda, Bargarh, Dhenkanal, Cuttack, and Bhadrak. The Western districts of Sundergarh, Sambalpur, Bargarh, Bolangir, Kalahandi, and Mayurbhanj with maximum temperature hovering between 40-46° C are warm almost throughout the year and remains intolerably cool in winter. The climate is equable but highly humid and sticky in the coastal districts.

3. The relative humidity for all districts ranges between 65-80 %. Ganjam district of Odisha has highest relative humidity with the mean relative humidity of 81.65% followed by Jagatsinghpur with the mean relative humidity of 80.41%. Bolangir has shown the lowest relative humidity with the mean relative humidity of 67.69%.

4. Econometric techniques have been applied to aggregate the data in a panel form from the year 1995-2015. The data had been aggregated in a balanced panel data set which enables for the accuracy of the results of the analysis.

5. Panel data models used in this study are pooled estimator, fixed effects model, and random effects model. The pooled effect model concludes that relative humidity has a significant effect and total rainfall, average maximum temperature, and average minimum temperature have shown no significant effect. Both fixed effects model and random effects model had concluded that relative humidity has the significant effect, but rainfall, maximum temperature, and the minimum temperature had no significant effect. Hausmann test is done to differentiate between fixed effects model and random effects model in panel data where random effects model is kept under null hypothesis due to higher efficiency and the alternative hypothesis is taken for fixed effects model

is at least as consistent. F-test had also been analyzed for no fixed effects as to reject the null of poolability. Both the test Hausmann test and F-test had concluded that null hypothesis is rejected. Hence fixed effects model is accepted to study the impact of climate change on rice, but as the estimation had shown that total rainfall, average maximum, and minimum temperature are not significant and relative humidity is only significant so it is suggested that fixed effect model is not preferable to study the impact of climate change. The variation is may be due to the unavailability of the maximum temperature and minimum temperature for all districts. Other Da Silva method had also shown that total rainfall, maximum temperature, and minimum temperature are not significant and relative humidity has shown the significant effect. Among the entire panel data models only Parks methods have shown the significant effect in all the weather parameters, hence it concludes that parks method is appropriate to study the impact of climate change on rice in Odisha.

6. The whole study has revealed that with the slight fluctuation in the weather parameter may affect the production of rice. There is a variation in a rainfall and the scarcity of rainfall may decrease the production. With the increase in maximum temperature and the decrease in minimum temperature lead towards the loss of production. The fluctuation in relative humidity may lead towards the loss of production.

CONCLUSION

The study attempts to find out the impact of climate change on rice in Odisha by using Panel data. Odisha state covers an area of 1, 55,707 sq.km.having a coastline of about 480 km on the Bay of Bengal. It lies between 17° 31' and 22° 31' The Western Rolling Uplands are lower in elevation, 153-305 m and have bedrock of hard soil and a lot of flora and fauna. 31' N latitude, 81° 31' and 87° 3°' E longitude. It can be broadly divided into five major regions. The coastal plains in the East, the middle mountainous and highlands region of north and northwest, the central plateaus, the Western rolling uplands and the major flood plains. The region stretches from the West Bengal border i.e. from the river Subarnarekha in the north to the river Rushikulya in the South. This region slopes eastwards, maximum width in the middle as the Mahanadi delta, narrow in the North Balasore plain comprising deltas of the Subarnarekha and the Budhabalanga and narrowest in the South Ganjam plain comprising smaller delta of the Rushikulya. The South coastal plain also comprises the laccustrine plains of Chilika Lake. The long stretch of land covers the districts of Balasore, Cuttack, Puri and a part of Ganjam with miles and miles of paddy fields constituting the 'rice bowl' of the State. The time period from 1995 to 2015 has been taken into consideration to study the impact of climate change on rice. The impact of different weather variables on rice production of Odisha had been studied using panel data analysis. Rice production was taken as dependent variable; average maximum temperature and minimum temperature and relative humidity as climatic variables were taken as input control variables. The study was based on panel data approach which focuses on changes in climatic behavior on production of rice as a dependent variable. Due to unavailability of data for temperature and relative humidity for all districts, the data for 20 districts had been taken into consideration to show the variation in climate change. The descriptive statistics has been used to study the variability in weather parameters by calculating the mean, standard deviation and coefficient of variation. It concludes that northern Odisha have highest rainfall which enables them to have better production followed by western Odisha also have medium rainfall and it also contributes great production with Bargarh district which contributes to have highest production among all districts of 12,384 kg per tones. The warm temperature with maximum temperature prevails in western Odisha of Bargarh district having the highest maximum temperature of 33.36^{o} C followed by the eastern district Khurda. The minimum temperature is highest in eastern district Puri of Odisha with temperature of 24.10°C followed by Dhenkanal district. Southern district Koraput of Odisha has lowest minimum temperature with 17. 35°C.The relative humidity is highest in Ganjam district with the mean relative humidity of 81.65% followed by Jagatsinghpur with the mean relative humidity of 80.41%. Bolangir has shown the lowest relative humidity with the mean relative humidity of 67.69%. Three models have been taken to study the impact of climate change on rice; Pooled model, fixed effects model, Random effects model, Da Silva method estimation and Parks method estimation have been taken into consideration. The results found in pooled estimate that total rainfall, maximum temperature, minimum temperature and relative humidity are not significant while relative humidity has shown significance. Fixed effects model has shown that rainfall, average maximum and minimum temperature and relative humidity have shown not significant. Random effects model concludes that rainfall, average maximum temperature and average minimum temperature are not significant and relative humidity have significant effect. Da Silva method has shown no significant effect in rainfall, maximum temperature and minimum temperature and relative humidity is significant and Parks method have shown that rainfall, average maximum temperature and average minimum temperature and relative humidity have significant effect.

The panel model concludes that Parks method is appropriate to study the impact of climate change on rice. The whole study revealed that scarcity of rainfall may drastically affect production and with the increase in average maximum temperature may leads towards the destruction of crop. With the decrease in the minimum temperature may leads to the loss of production as rice don’t require cooler climate. With the fluctuation of relative humidity, it leads towards the loss of the rice crop.

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