IMPACTS OF CLIMATE FACTORS INFLUENCING RICE PRODUCTION IN BANGLADESH

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ABSTRACT

This study aims to study the climate change pattern, assess the situation of climate change, finding the influences of climate change on the production of rice, estimating a model between climate change and rice production in Bangladesh. Ordinary Least Squares (OLS), Generalized Least Squares (GLS), Feasible Generalized Least Squares (FGLS) were used in this study to compare the results.
This study included all 64 districts of Bangladesh with a time span from 2011 to 2018.
It included panel data of the production of Aus rice, Aman rice, Boro rice as well as HYV of each rice (Aus, Aman, Boro) of 64 districts of Bangladesh for agricultural data, temperature, rainfall and humidity of 64 districts for climate data. This study estimates the stochastic production function formulated by *Just and Pope (1978, 1979),* which allows the effect of inputs on the mean yield to differ from that on yield variance. The results showed that increased climate variability, climate extremes; in particular, exacerbate risk on Rice production in Bangladesh. Rice yields are sensitive to rainfall extremes, with both deficient and surplus rainfall increasing variability. For 1% increase in annual total rainfall, Mean Yield will decrease by 0.139%, 0.141%, 0.132% in OLS, GLS and FGLS method respectively, if other variables remaining the same. For 1% increase in annual average percentage of humidity, Mean Yield increases by 1.352%, 1.340%, 1.362% in OLS, GLS and FGLS method respectively, if other variables remaining the same. for 1% increase in HYV area, Mean Yield increases by 0.831% in OLS, GLS and FGLS method, if other variables remaining the same. Additionally, climate inputs, non-climate input, high yielding variety seeds are found to increase average yield.

Keywords: Climate change, Rice, Panel data, Temperature, Humidity, Rainfall, Bangladesh

1. INTRODUCTION

Regarding the impact of global warming and climate change issues, Bangladesh is identified worldwide as one of the most vulnerable countries because of its unique hydro-geographic location, low elevation from the sea, dominance of floodplains, high levels of poverty, high population density, and over dependence on nature and natural resources for agricultural production. Bangladesh has got a long history of several extreme climatic events. The variation in rainfall pattern has been combined with increased snow melt from the Himalayas and temperature extremes. These have been resulted in crop production failure and damage, preventing farmers and those dependent on meaningful earning opportunities.

The majority of Bangladesh's population is dependent on agriculture which is highly influenced by climate variability and change. Climate change and global warming are causing threats in settlements and leading to the displacement of the number of people from their land due to riverbank erosion, permanent inundation, and sea-level rise which are increasing rapidly every year. It is alarming that resources and efforts of government and people are quickly drained addressing the impact of one event when another hazard strikes. Consequently, the impacts of global warming and climate change have been challenging our development efforts, livelihood security and sustainability constantly. However, the international community recognized that Bangladesh ranked higher than other vulnerable countries due to climate change.

Following India, China, Indonesia,-Bangladesh is the fourth largest rice producing country in the world (IRRI, 2008). The vegetative and reproductive growth of every crop is mediated by a temperature range factor. The crop production faces constraints when the temperature falls below the range or exceed the upper limit. Existing studies from the U.S. and India find that extreme heat does not seem to affect crop mix or input use and that yields are affected by long-term changes in climate patterns (Burke and Emerick, 2016, Guiteras, 2009).

There are a few studies conducted in Bangladesh about the impacts of climate change on rice production. Tuhin et al. (2016) consider daily maximum temperature, seasonal total rainfall, daily average humidity, and daily sunshine hour to observe the climatic variability and their impacts on the seasonal productivity of Aman rice. They say that maximum temperature and average seasonal rainfall increased slightly by 0.04°C and 0.09 mm and the average production of Aman rice increased by 0.03 ton per hectare at Dhaka region in Bangladesh. Sarker, Khorshed, and Jeff (2012) consider three variables which are maximum temperature, minimum temperature and rainfall and they use ordinary least square (OLS) method.

2. METHODOLOGY

This study aims to estimate the relationship between the mean yield of rice crops and climate variables to show the impacts of climate change on rice production. The dependent variable mean yield of rice crops expresses the mean yield of local Aus, local Aman, local Boro, HYV Aus, HYV Aman and HYV Boro rice production combinedly of each year from 2011 to 2018 for each district. On the other hand, temperature, rainfall, and humidity are considered as independent variables. High Yielding Variety of Aus, Aman, Boro rice combined is also considered as an independent variable. Previous studies used different units of time, such as months, phonological periods and growing seasons, for climate variables. However, this study has used annual time period of all the variables for each district of Bangladesh. The climate change trend, as well as rice productivity trend for all districts, is shown in division-wise histograms.

2.1 Empirical Model Specification - Regression models (Sarkar et al., 2012; Boubacar, 2010; Mendelsohn, 2009; Isik and Devadoss, 2006; You et al., 2005; Peng et al., 2004) and indirect crop simulation models (Schlenker and Roberts, 2008) are used in most of the study on possible effects of climate variability and change on food crops. Also, Feasible Generalized Least Squares (FGLS) and Maximum Likelihood Estimation (MLE) can be used. However, FGLS estimation is employed in most empirical studies, although MLE is more efficient and unbiased than FGLS for small samples (*Saha et al. 1997*). Given the large sample size here, FGLS was used, as described in *Judge et al. (1988)*, to estimate a form of fixed effects panel model.
The panel data used in this study shows that it follows a normal distribution when histograms of rice mean yield against time were drawn. Non-climatic factors such as improved variety, management techniques, fertilizers, pesticides may cause changes in the mean yield of rice. Therefore, we need to remove the mean yield trend caused by non-climatic factors before we run our linear regression model. To remove the non-climatic trend and avoid heteroskedasticity in the linear regression model, we can use a log-linear regression model. Log-transformation can transform absolute differences into relative differences.

Regression equation estimated for rice is:

$$\mathbf{lnMean\ Yield_{it} = \beta_1 + \beta_2\, lnTemperature_{it} + \beta_3\, lnRainfall_{it} + \beta_4\, lnHuimidity_{it} + \beta_5\, lnHYV_{it} + v_{it}}$$

where lnMean $Yield_{it}$ refers to the natural logarithm of mean yield of rice and i refers to the district and t refers to the year; β_1 denotes district level fixed effects; $lnTemperature_{it}$ is the natural logarithm of average temperature; $Rainfall_{it}$ is the natural logarithm of annual rainfall; $lnHumidity_{it}$ is the natural logarithm of annual humidity; lnHYV is the natural logarithm of mean yield of high yielding varieties and v_{it} is stochastic error terms where $v_{it} \sim N(0,1)$.
In our model specification we do not include inputs such as irrigation and fertilizer in the regression. Irrigation is likely to reduce production risk (Foudi and Erdlenbruch 2011) though some argue otherwise (Guttormsen and Roll 2013). Fertilizer use typically increases production risk even as it increases

expected output (Just and Pope 1979, Rosegrant and Roumasset 1985, Roumasset et al.1987, Ramaswami 1992, Di Falco, Chavas, and Smale 2007). However, since the two are correlated with each other and also with HYV use their interactive effect is unclear and we leave this for further research.

2.2 Data Sources- Annual yield data of both local and high yielding varieties of three different rice crops (Aus, Aman, Boro) for the period of 2011-2018 were obtained from Yearbook of Agricultural Statistics of Bangladesh (2017, 2015, 2013, 2011), Department of Agricultural Extension (DAE) and website of the Bangladesh Bureau of Statistics (BBS). These data were found according to the fiscal year, such as 2017-2018, 2018-2019, etc. Then, these fiscal year data were transformed into yearly data, for example, 2017-2018 was considered as 2018.
Secondary data on monthly average temperature, monthly average total rainfall and humidity data from 2011 to 2018 has been collected from all 34 weather stations of the Bangladesh Meteorological Department (BMD) located all over Bangladesh. The three independent variables used for this study from this dataset are rainfall, temperature, and humidity. Rainfall is defined as the 12 month summations of monthly rainfall values. Temperature is the 12 month average of monthly average temperatures. Humidity is defined as the 12 month average of monthly average relative humidity.

2.3 Panel unit root test – A panel unit root test had conducted by STATA to see the expected result. To estimate the result of panel unit root, all the tests had been run.

The hypotheses are-
H_0: Panels contain unit roots
H_1: Panels are stationary
We reject the null hypothesis when $p<0.001$.

2.3.1 Levin Lin Chu test This test can be performed only when the panels are non-stationary and to test the stationarity of the series, panel unit root test were run based on the null hypothesis of unit root. Results reported in Appendix.I show that all variables were found to be accepting the null of common unit process at level but rejected the null hypothesis at first difference and thus we concluded that all variables were found to be stationary at first difference. All variables were tested for non stationarity and found to be stationary.

2.3.2 Harris Tzavalis test
All variables were tested for non stationarity and found to be stationary. The table of result is shown in Appendix.I.
2.3.3 Breitung test
This result has 37% p-value and therefore contains unit roots. The table of result is shown in Appendix.I.
2.3.4 Im Pesaran Shin test
All variables were tested for non stationarity and some panels are found to be stationary. The table of result is shown in Appendix.I.
2.3.5 Augmented Dicky Fuller and Phillips Perron test
The present study focuses on the effects caused by climate variation on different rice crops and thus each variable under the study must have zero degree of integration, otherwise the variables cannot be used for correlation, causality, and OLS estimations if they characterize different degrees of integration.

Table.1: Results of Unit Root Test (Augmented Dickey-Fuller & Phillips-Perron Tests)

Variables	Integration of order for Mean yield of Rice
lnMeanyeild	I(1)
lnTemperature	I(0)
lnRainfall	I(0)
lnHumidity	I(0)
lnHYV	I(0)

**MacKinnon (1996) one-sided p-values (at 1%, 5% & 10% level is -3.605, -2.936& -2.606 respectively) is used.*
Source: Author's own estimation.

2.4 Testing for fixed versus random effects In testing for fixed versus random effects, Hausman test were performed and random effect model was found to be appropriate (Appendix.IV).

In light of the above results, panel corrected standard error (PCSE) estimates were obtained, which correct for cross sectional dependence, heteroscedasticity and autocorrelation. The parameters are estimated using a Prais Winsten (or OLS) regression. Equations have been estimated with district and year fixed effects.

Regression was run for rice, explaining mean yield. Mean yield depends on climate and non-climate inputs. Our results, however, show mean yields are best explained by levels of rainfall and temperature. We surmise therefore it is variability in climate that makes agriculture more risky.

3. RESULTS AND DISCUSSION

Climate data in the time span from 2011 to 2018 shows the pattern of changes in Rainfall, Temperature and Humidity all over the country divided into its divisions (Dhaka, Chittagong, Sylhet, Rajshahi, Rangpur, Khulna, Barishal and Mymensingh).

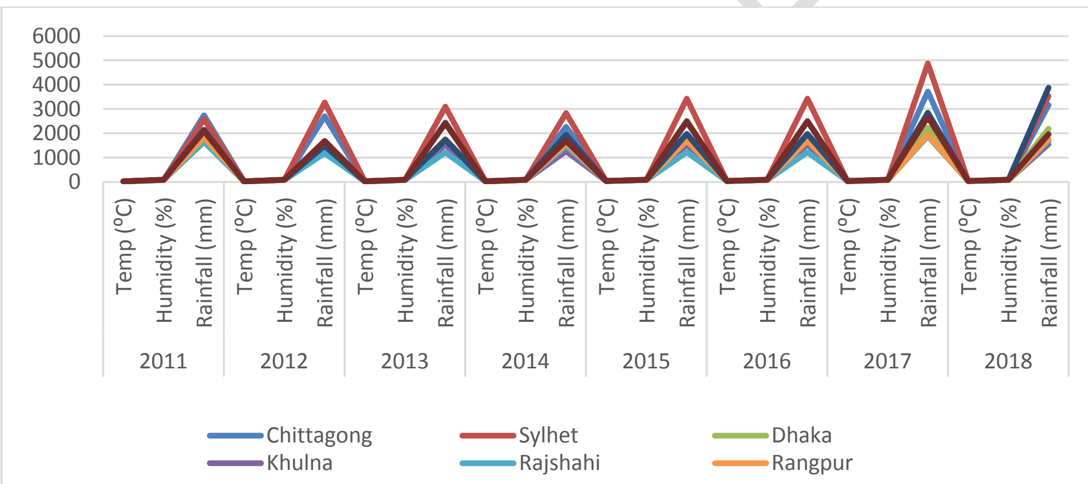

Fig. 1. Climate change pattern in Bangladesh over the period of 2011-2018 (Division-wise)

This study found an irregular pattern of changes in Temperature while Rainfall and Humidity show an increasing trend over the years in all divisions of the country (Fig. 1). In 2011, the lowest annual average temperature was recorded in Rangpur division (25.04^0C) while the lowest annual average temperature of 2018 was recorded Dhaka division (29.62^0C). Similarly the highest annual average temperature was recorded in Barisal (26.09^0C) in 2011 while the highest annual average temperatures of 2018 were recorded both in Khulna and Rajshahi divisions (30.83^0C). In the case of temperature, it is evident that despite many upper and lower temperature fluctuations, the trend is going upward. The lowest annual average humidity in 2011 was recorded in Dhaka division (75.77%) and the lowest annual average humidity in 2018 was also in Dhaka division (74.54%). Then, the highest annual average humidity in 2011 was recorded in Barisal division (82.83%) and the highest annual average humidity in 2018 was also in Barisal division (82.17%). Though the lowest and highest recorded annual average humidity seems to be decreasing over time, the difference between the low and high points are not negligible. The fluctuations of rainfall are greater than temperature and humidity according to the results. The lowest annual average rainfall in 2011 was recorded in Rajshahi division (1645.38mm) and the lowest annual average rainfall in 2018 was also in Khulna division (1553.80mm). Then, the highest annual average rainfall in 2011 was recorded in Chittagong division (2743.82mm) and the highest annual average rainfall in 2018 was also in Mymensingh division (3874mm). While comparing, it is found that though the lowest annual average rainfall has decreased over the years but the highest annual average rainfall has been increased. This indicates that the event of sudden irregular fluctuation of rainfall has happened over these years.

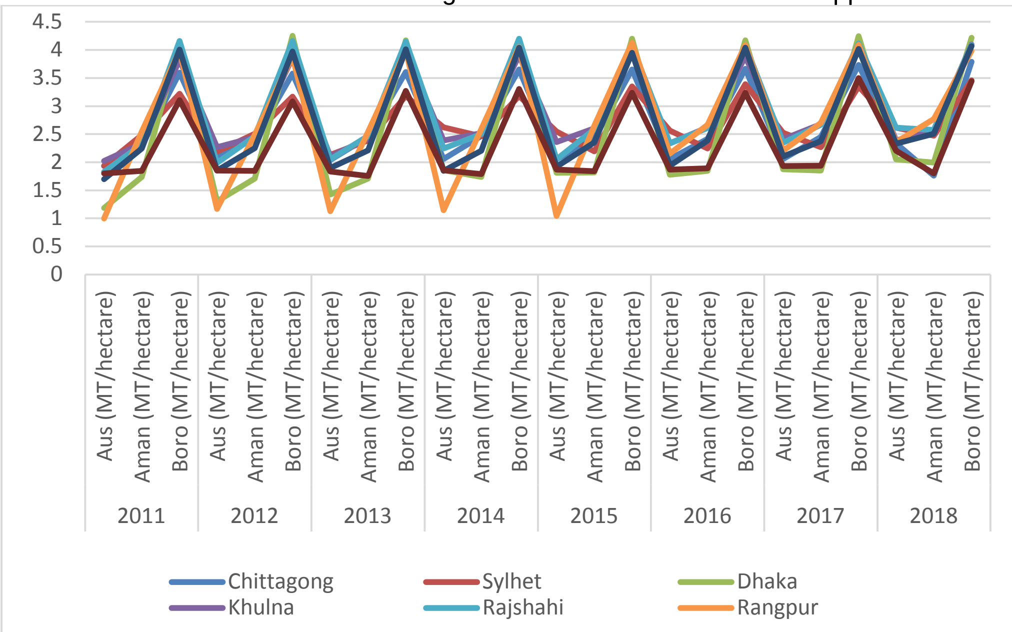

Fig 2: Rice productivity trends in Bangladesh over the period of 2011-2018

Rice productivity trend for Aus, Aman and Boro rice is shown in Fig.2, where it is evident that Boro rice productivity in metric tons per hectare hits the highest score while Aman rice is moderately productive and Aus rice has low productions over the years. In Rangpur division, Aman rice productivity increases significantly over the years.

<u>Results for the Model using Mean Yield of Rice for OLS, GLS, FGLS:</u>

Table. 2. Results for Mean Yield Model

	OLS				GLS				FGLS			
MY	**Coef.**	**Std. Err.**	**t**	**P>t**	**Coef.**	**Std. Err.**	**z**	**P>z**	**Coef.**	**Std. Err.**	**z**	**P>z**
Temp	0.866	0.625	1.385	0 .083	0.830	0.629	1.320	0.093	0.856	0.622	1.376	0.084
Rain	-0.139	0.048	-2.929	0.002	-0.141	0.047	-3.012	0.001	-0.132	0.043	-3.086	0.001
Hmdt	1.352	0.490	2.759	0.003	1.340	0.446	3.007	0 .001	1.362	0.428	3.179	0.001
HYV	0.831	0.041	20.505	0.000	0.831	0.041	20.059	0.000	0.831	0.040	20.608	0.000
_cons	-5.485	4.088	-1.342	0.180	-5.309	4.160	-1.276	0.202	-5.485	4.068	-1.348	0.178
R^2	0.426				0.543				0.394			
F(4,497)	112.36											

The table above shows the results of regression parameters and their respective standard errors and *p* values for Mean Yield specification using three estimators. The aim is to check reliability by verifying whether the estimates vary with respect to the different estimators. The yellow, green and blue paints show the slight differences in the standard error depicting which estimator has the lowest standard error.

This implies that the difference between OLS and GLS is in the variance of the estimates. And the real reason, to choose, GLS over OLS is indeed to gain asymptotic efficiency (smaller variance for n →∞. It is important to know that the OLS estimates can be unbiased, even if the underlying (true) data generating process actually follows the GLS model. If GLS is unbiased then so is OLS (and vice versa).

Ordinary least square regression analysis is conducted for Mean Yield. Standardized beta coefficients of annual total rainfall, annual average percentage of humidity and area cropped under HYV seeds are found to be significant with t value of -2.929, 2.759 and 20.505 respectively. The associated probabilities for the variables also stood at *P*<0.01. We reject the null hypothesis and conclude, there is sufficient evidence that beta coefficients of annual total rainfall, annual average percentage of humidity and area cropped under HYV seeds are significantly different from zero. Average temperature variable in the model is insignificant as P values are more than 0.05. The OLS model fits the data well at 0.10 significance level (F=112.360and P<0.01). R^2 -Adjusted of 0.4706 says that this model accounts for 47.06% of the total variance in the mean yield of Rice. Therefore the model of OLS regression analysis for the mean yield is-

$$\ln Mean\ Yield_{it} = -5.485 + 0.866\ \ln Temperature_{it}\ -0.139\ \ln Rainfall_{it} + 1.352\ \ln Huimidity_{it} + 0.831\ \ln HYV_{it} + v_{it}$$

In OLS model, for 1% increase in annual total rainfall, Mean Yield will decrease by 0.139%, ceteris paribus. For 1% increase in annual average percentage of humidity, Mean Yield increases by 1.352%, ceteris paribus. And on average, for 1% increase in HYV area, Mean Yield increases by 0.831%, ceteris paribus.

Generalized least square model were also computed, panels are homoscedastic with no autocorrelation. Total of 512 observations were analyzed using four explanatory variables. It is seen from the model that the variable rainfall, humidity andHYV Area are significant. Furthermore, when compared Generalized least square model with Ordinary least square there seems to be not much difference observed among standardized beta estimates as both the estimators reveals similar results when Mean Yield is used as a dependent variable. The GLS model fits the data well at 0.05 significance level, (chi= 430.00, P<0.001) and interpretation of estimates for GLS estimator is like the OLS estimator. Estimates obtained from Generalized Least square estimator are the same with those of Ordinary least square. Further, investigation was computed using the estimated or feasible generalized least square. Estimates proves more efficient when compared to OLS and GLS model but with the disadvantage that the standard error estimates are conditional on the estimated disturbance covariance and this is validated by Beck and Katz (1995). The model of GLS regression analysis for the mean yield is-

$$\ln Mean\ Yield_{it} = -5.309 + 0.830\ \ln Temperature_{it}\ -0.141\ \ln Rainfall_{it} + 1.340\ \ln Huimidity_{it} + 0.831\ \ln HYV_{it} + v_{it}$$

Mean Yield as a dependent variable with HYV Area is the significant variable in the model, standard errors of the FGLS model when compared with OLS and GLS models are more reliable and consistent. The FGLS regression analysis for the mean yield is-

$$\ln Mean\ Yield_{it} = -5.485 + 0.856\ \ln Temperature_{it}\ -0.132\ \ln Rainfall_{it} + 1.362\ \ln Huimidity_{it} + 0.831\ \ln HYV_{it} + v_{it}$$

Based on the mean yield specification for OLS, GLS and FGLS, the constant term is negative with values of 5.485, 5.309, 5.485 respectively. This means that those stochastic factors not included in the model have a negative influence on performance.

4. CONCLUSION

Using 8 years district level panel dataset for rice in Bangladesh, this study finds that increased climate variability; climate extremes in particular, exacerbate risk. Rice yields are sensitive to rainfall extremes, with both deficient and surplus rainfall increasing variability. In addition to climate inputs, non-climate input, namely, high yielding variety seeds are found to be increasing average agricultural yield. As the econometric results could be subject to omitted variable bias, we leave it for further research to employ a richer set of mean and variability shifters than employed in this paper. Based on the mean yield specification for OLS, GLS and FGLS, the constant term is negative with values of 5.485, 5.309, 5.485 respectively. This means that those stochastic factors not included in the model have a negative influence on performance. The analysis presented in this study has important policy implications. Higher variability in agricultural production will lead to greater variability in incomes of the rural poor, who already face severe financial and credit constraints. Hence, it is imperative to undertake suitable policies to mitigate climate change impacts on this sector to the extent possible.

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APPENDIX

Appendix. I

Levin-Lin-Chu unit-root test

	Statistic	p-value
Unadjusted t	-2.20E+02	
Adjusted t*	-2.40E+02	0.000

Harris-Tzavalis unit-root test

	Statistic	z	p-value
rho	-0.115	-18.75	0

Breitung unit-root test

	Statistic	p-value
lambda	-1.4272	0.0768

Im-Pesaran-Shin unit-root

	Statistic	p-value
W-t-bar	-24.0771	0

Results of Unit Root Test (Augmented Dickey-Fuller & Phillips-Perron Tests)

Variables	**Integration of order for Mean yield of Rice**
logMeanyeild	I(1)
logTemperature	I(0)
logRainfall	I(0)
logHumidity	I(0)
logHYV	I(0)

Appendix. II

Descriptive Statistics for Panel Data with Skewness and Kurtosis

Variable	**Mean**	**SD**	**Min**	**Max**	**Skewness**	**Kurtosis**
lnMeanyeild	11.796	0.955	8.945	22.355	0.0000	0.0000
lnTemperature	3.265	0.050	3.028	3.429	0.0002	0.0000
lnRainfall	7.551	0.345	6.968	8.690	0.0000	0.8739
lnHumidity	4.361	0.041	4.234	4.443	0.0000	0.0000
lnHYVarea	11.576	0.782	9.471	13.114	0.0000	0.6028

Appendix. III

Using VIF to test for multicollinearity for mean yield of Rice

	logMeanyield	
Variable	VIF	1/VIF
lnHumidity	1.12	0.891681
lnRainfall	1.1	0.912619
lnHYV	1.03	0.974707
lnTemperature	1.01	0.985826
Mean VIF	1.06	

Appendix. IV

HAUSMAN RESULT

	coefficients			
	(b) fe	(B) re	(b-B) differences	sqrt(diag(V_b-V_B)) S.E.
lnTemperature	-0.06986	0.829804	-0.8996601	0.4338332
lnRainfall	-0.16188	-0.14108	-0.0208072	0.131385
lnHumidity	-0.1411	1.339541	-1.480645	2.271562
lnHYVarea	0.887346	0.831387	0.055959	0.1165415

Appendix. V

Results for Mean Yield Model

	OLS				**GLS**				**FGLS**			
MY	**Coef.**	**Std. Err.**	**t**	**P>t**	**Coef.**	**Std. Err.**	**z**	**P>z**	**Coef.**	**Std. Err.**	**z**	**P>z**
Temp	0.866	0.625	1.385	0 .083	0.830	0.629	1.320	0.093	0.856	0.622	1.376	0.084
Rain	-0.139	0.048	-2.929	0.002	-0.141	0.047	-3.012	0.001	-0.132	0.043	-3.086	0.001
Hmdt	1.352	0.490	2.759	0.003	1.340	0.446	3.007	0 .001	1.362	0.428	3.179	0.001
HYV	0.831	0.041	20.505	0.000	0.831	0.041	20.059	0.000	0.831	0.040	20.608	0.000
_cons	-5.485	4.088	-1.342	0.180	-5.309	4.160	-1.276	0.202	-5.485	4.068	-1.348	0.178
Adj R^2	0.4706											
F(4,497)	112.36											