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Impact of Weather on Household Welfare: Cross Sectional Evidence from Bangladesh

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Abstract
This study aims to determine how Bangladeshi household welfare varies depending on the weather. The Household Income Expenditure Survey (HIES) 2016 data and historical Bangladeshi monthly rainfall data are both used in this study. The log of per capita consumption and the food diversity index serve as measures of the welfare at the household level. The numerous illnesses, such as pneumonia, fever, and diarrhea, are used to gauge an individual's level of welfare. This study discovers that rural households' log per capita consumption grows by more than 3% more than that of other households on average for every unit increase in rainfall. Furthermore, food diversification has benefited from rains. Rainfall generally raises the food diversity index, which raises the diversity of foods. This implies that rainfall on average increases households' welfare.
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I. Introduction

People's health and economic circumstances worldwide, in both developed and developing countries, are substantially impacted by weather shocks. Extreme summer heat has been found to have a significant negative influence on people's health across Asia, Europe, and North America. Weather shocks result in crop failure, which seriously harms low-income people by raising food prices (Castello, Mcmichael and Montogomer, 2012). The primary victims of these shocks are rural households in both emerging and developed nations. Agriculture is one of the industries most impacted by extreme weather (WHO, 2008).

Excessive rainfall affects food security and necessary expenditures of households. Also, the extreme weather events cause frequent floods and storms that outbreaks diseases like cholera, diarrhea especially by contaminating water and causes scarcity of sanitation and safe water service. These diseases cause malnutrition, increase mortality rate of children, and sometimes affect the growth patterns of the surviving children. The health endowment and infrastructure are low in the developing countries and children's immune systems and physiology are not well developed. Children seem to be mostly affected by climate change (IPCC, 2007; Islam, Alam, & Afzal, 2021).

The extreme temperature and excessive deluge affect the child health of rural areas along with lowering living standards of rural households. Researchers from IOCAD (International Center for Climate Change and Development) find the rural areas of Bagerhat and Gopalganj areas where women and children suffer the most in the weather-related shocks. Diseases like Diarrhea, Pneumonia, Amasha and high fever remain very common among children during flood season (Ahmed, 2014). The cost of Diarrheal diseases is estimated to be increased by 2% to 5% within 2020 (Rahman, 2008).

A study conducted by Hossain, Hasan, Alaudin and Akther (2017) have unfolded predictions about future patterns of rainfall. Several research have been found which were conducted on the issue of precipitation of Bangladesh. Basak et al and Farhana (2011) have conducted research on the trends of rainfall in Bangladesh in different seasons where they found that total rainfall showed increasing trend for monsoon and post monsoon seasons which is mainly from June to October whereas in winter seasons there is decreasing trend of rainfall. Though several researchers agreed on the fact that rainfall has increased over pre-monsoon, monsoon and post monsoon. Some argued that average rainfall has decreased. (Roy.M,2013).Rahman and Latheh (2015) observed downward trend of the average rainfall in the pre-monsoon which doesn't match the observation of Shahid.S(2010) and Hasan et al (2014).

The variation in rainfall indicates an erratic rainfall pattern due to climate change in Bangladesh (Hossain, Hasan, Alauddin. & Akther, 2017; Uddin, Datta, Alam, & Pavel, 2020). Though some researchers have come up with different results based on analytical methods, data types and different study areas, the rainfall data they used are multidimensional. Basak et al (2013) find no change in the pre-monsoon and saw increasing trend in monsoon and post monsoon which is not consistent with the result of the study done by Hossain.M, Hasan. Z.M,

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Alauddin. M & Akther. S, at 2017.

Inconsistency is found due to the analysis of individual months by Hossain et al 2017 whereas Basak et al (2013) analyzed seasonal variations. On the other hand, Hasan et al (2014) found that there is increased average annual and pre-monsoon rainfall, and this result he found by doing a trend analysis using Mann-Kendall method but their research result is inconsistent with the result of Shahid (2010) worked on 17 stations and using the rainfall data of 1958-2007. The monthly maximum rainfall data pattern illustrated that heavy rainfall occurred in the late monsoon and late pre monsoon was expected in early of the monsoon that is defined as erratic rainfall. So, by analyzing all the research done in the context of rainfall pattern of Bangladesh we can reach in the conclusion that overall rainfall in Bangladesh decreased over the total time period that may also continue in future and in case of monthly mean and monthly maximum rainfall expected rainfall pattern in the early monsoon would be replaced by comparatively wet last monsoon.

In this paper, we show the impact of weather on households' welfare of Bangladesh by applying OLS estimates of household's log of per capita consumption and food diversity and logit estimates of several frequent diseases. To analyze the welfare impact induced by rainfall, data have been taken from the Household Income Expenditure Survey (HIES) 2016 from BBS and the historical monthly rainfall data of Bangladesh. The main objective of the study is to measure the impact of weather through rainfall variability on household welfare.

This paper is organized as follows. Chapter II discusses about the previous literatures regarding this issue, chapter III describes about Bangladesh's historical rainfall analysis, chapter IV describes the data sources of this analysis, chapter V expresses the variables of this analysis with the estimation strategy, chapter VI describes the descriptive statistics, chapter VII analyses the regression results, where chapter VIII and IX concludes the paper with limitations of the study and predictions of future research.

II. Review of literature

People of rural areas mostly depend on agriculture for maintaining their livelihood. In rural areas of the developing country, there are hardly any other activities available without agriculture for livelihood. The production of Agriculture vastly depends on weather (Guiteras, 2009, Blanc 2012, Malla,2008). Temperature and rainfall shocks have a long chain of causation cycle as these shocks hamper agricultural productivity, health of adults and children, educational attainment (Beizabih et al 2014, Lesk, Rowhani and Ramkutty,2016).

Weather shocks hamper agricultural productivity by decreasing the fertility of land as well as soil erosion due to flash floods occurred by excess of rainfall (Malla,2008).Adoption techniques of those shocks are not so efficient to cover up the losses (Schelenken and Lobell,2010).As a least developed country Bangladesh is dependent mostly on agriculture for food security also about 20% of GDP of Bangladesh is contributed by agricultural sector.85% people from rural areas of Bangladesh dependent on agriculture. As a tropical low land country Bangladesh is also vastly affected by weather shocks. Flash floods in the rainy season and increased temperature affects agricultural production (Sikder & Xiaoyin,2014, Chowdhury and Khan, 2015). The IPCC (2007) has projected that temperature of Bangladesh may on average rise to 2.4 degrees during 2030s and these projected temperature may cause to reduce rice production by 8% to 17%.

The shocks occurred due to weather variability has impact on health which not only has a direct effect on long term socioeconomic outcomes but also it has effect on educational attainment which channels through to affect long term well-being. Researchers have found significant evidences of weather shocks transmitted impact on household's well-being by causing income shocks, hampering food security in rural and wetland areas (Alam and Hossian, 2018), health and educational attainment of children of those households. This impact not only limited in individual household rather it violates Social welfare and hampers poverty reduction process. A significant shortfall of rainfall caused approximately 14% reduction in household's per capita expenditure which leads to reduction in health and education and that has a long term impact (Skoufias,2013).5% increase in minimum temperature reduce the food consumption by more than 3% in Uganda while in maximum temperature the consumption reduced by 14%.(Lazzanori,2013).

Several number of studies found that rainfall shocks and temperature shocks affecting economic growth, capability to properly use the expenditure and nutritional status of rural households (Akobeng,2017, Alam and Hossain, 2018, Baez et al 2016, Pol,2018,Ali 2012,Maccini and Yang 2009,Hunton,2011).Timing of those shocks is also relevant in the context of food and nonfood consumption criteria in rural Mexico (Skoufias,Vinha & Katja,2012).

According to the prospective of Bangladesh it is also see that several extreme weather events like cyclones, flash floods and heat waves caused excessive harm to those households living in that area of weather shocks. Rural infrastructure of those areas also got violated by these shocks (Alam and Hossain, 2018, Hossain et al ,2008). Despite of such hazardous impact of these shocks' adaption techniques of these shocks adaption techniques of these shocks are not standard enough. Also, women of Bangladesh are more likely to suffer due to these shocks. (Uddin, Datta, Alam, & Pavel, 2020; Alam & Zakaria, 2013; Davids & Ali, 2014).

Weather shocks have significant impact on health of the households living in the shock prone area comparing to the whole country. There exists a vast number of literatures explaining impact of weather shocks on health. By violating agricultural productivity this shock affects nutritional intakes, health expenses and so on. Weather shock mostly defined as rainfall deficiency and temperature shocks and these shocks are likely to spread disease like Diarrhea, Malaria, Dengue, Lyme etc (Alam & Zakaria, 2021; Bunyavanich et al 2013, Cornwell & Inden 2015, WHO 2000, Andalon et al 2014, Tucker and Gilland 2006).In Nepal monsoon rainfall shock significantly affects children's health through income shocks and moderate increase in rainfall leads to create a negative disease environment effect which then improve the anthropometric measure of children (Tiwari,Jacobs and Skoufias,2013).Air borne particles and weather conditions also causing significant harm to children.(Amarillo and Canneas,2012).

Children between the ages of 12 and 47 months are most prone to experience weather shocks, which result in short in height for those kids in Mexica (Skoufias and Vinha,2011). The main causes of epidemics of diseases like malaria and diarrhea in African nations are sudden changes in temperature and precipitation. These shocks might be dangerous for expectant moms (Bandyopadhay et al 2012, Kudumatsu,2012). A mother's ability to breastfeed may occasionally be reduced by excessive rain because of the increasing opportunity costs of productivity (Thai and Mynskyla, 2011). The standard deviation of the height for age and weight for height z scores can be used to understand the potentially harmful effects of weather shock on nutritional status.

Weather shocks increased the cost of fighting against those seasonal diseases from 0.2 to 0.5 of GDP of Sub-Saharan Africa within 2020 (Wang,Kanji and Bandyopadhay,2009).Weather shocks a have hazardous impact on mental health along with physical health too (Benny al,2011).Children's of Bangladesh have become the most suffered victims of weather shocks that occurred earlier stage of their life. Though environment of households, toilet facilities, excess of education to female members causes probability of child mortality to be decrease by 31.40% to 52.30%. (Mondal,Hossain and Ali,2009).Regional weather changes, excess rainfall, shortage of rainfall, heat waves etc. of shocks caused households to be suffered socio-economically. Cost of diarrheal diseases will be increased from 2 to 5% within 2020 along with food insecurity, spreading of other water borne diseases caused households to suffer extremely during those shocks. (Rahman,2008, Imai et al 2014, Sahid,2015).

The weather shocks used to process a contemporaneous effect and such effects may advocates of long-term implications of the shock. Several numbers of papers suggested that shocks happened in early stage of life due to weather change hampers the child's growth, educational attainment, even income when those children become adult (Decron and Porter,2010, Hoddinot and Kinsey 2001, Andalon e.t al 2014, Cornwell and Hinder 2014,Cook et al 2008,Umannaponte, 2011).Extreme weather shocks affects child's schooling along with several health related haphazard. Rainfall shock during third year of life and pregnancy is crucial for health and Schooling.(Thai and Falanis,2014).The shocking famine occurred 1984 in Ethiopia lessen the height of affected children and their completed years of schooling which in turn reduced their income by 3 to 8% (Decron & Porter,2010).Similar sorts of results are found in the study o regarding on the context of 1980 famine in Uganda.(Umannaponte,2011).Positive weather shocks which means that standard amount of rainfall may improve the educational attainment for female (Maccini and Yang,2009).

Researchers also found that stunned children due to malnutrition & disease seemed to catch up with time though they seemed to perform less than those who were not affected by shocks and according to those researchers catch-up growth mainly depends on biological characteristics of parents, specially mothers (Desmond and Cassale,2015,2017).But there are other branch of researchers who disagreed on the above fact they rather agreed on the fact that early stage of life don't have that long term growth as children's showed substantial catch-up growth (Maccini and Young, 2009, Lunden e.t al, 2013, Tiwari, Jacobs & Skoufias, 2013, Rabassa, Skoufias and Jacoby, 2012). Catch-up growth mostly depends on puberty time nutrition intake (Hinuinen, 2013).

In general, gender discrimination regarding nutritional intakes, health facilities, years of schooling etc. mostly found in rural areas of developing countries. Weather shock also affects women by causing decrease in their test scores, lessen the ratio of school enrollment. Also, female children tend to have lessen number of nutritional intakes boys (Behnman and Devlaikan, 1990, Nyquast, 2013). In rural areas female children faced most discrimination after any kind of extreme weather event like drought floods, which in turn causes famine that increases the mortality rate of female children to increase (Das Gupta, 1987, Mu and Zhang, 2008, Sabarwal, Sinha and Buvinic, 2012). In Pakistan households are seemed to more income and price elastic on girl's demand for health care.(Alderman and Gertler,1997).Indonesian families tend to cut off educational expenditure of girls than boys in response to crop loss.(Cameron and Worswick,2001).Indonesian females are more vulnerable to negative shocks of air quality (Jaychandran,2006).Another branch of researchers found that there is no significant difference in female and male on the issue of responding weather shocks (Rabassa, Skoufias and Jacoby,2012). There is no significant difference in after drought mortality where women have more employment (Flato and Kotsadam, 2014).

Weather shocks also sometimes vary depending on the timing like birth year rainfall shock have more significant impact than rainfall shocks prior to birth years for that it is identified that shocks in utero have not much influence on the result of weather shocks impact on long run outcomes. Rather it's the rainfall shock of first year of life has a long temporal reach on women's outcomes as the nutritional deprivation mostly follows weaning from breastmilk period. So, there's no evidence of biased gender discrimination before birth (Maccini and Yang,2009, Glewee and King, 2001). Favorable rainfall improves female's reported health status, along with height ,grades of schooling and standard deviation in asset index in Indonesian rural households (Maccini and Yang,2009).Overall female children's anthropometric measure is also improved by the positive weather change (Rose,1999).

The economic crisis occurred in 1998 in Indonesia had similar effects on boys and girls in the context of school enrollment rate, though older boys comparing to older girls seemed to have greater budget shares in education after that crisis. Also, in another study it is found that 1998 Indonesian economic crisis affected both boys and girls similarly (Levine and Ames,2003). Although there exists a numerous paper about the impact of weather on household's welfare this paper is unique on the context that here we used the historical rainfall data of Bangladesh from 1960 to 2015 of 35 stations of Bangladesh from Bangladesh Meteorological Department merging with household level data of Bangladesh Household Income Expenditure Survey 2016 which is quite unique according to the perspective of Bangladesh. Though Bandhapadhaya and Skoufias (2012) carries out a household level survey and historical climate data to portray welfare being of households by diversification of occupation during floods but our research is different from them as here we used Shannon Index to observe food security, as an indicator of welfare of rural households of Bangladesh which is quite unique in the perspective of Bangladesh's rural household's welfare status influenced by weather which is captured by log of monthly average rainfall.

IV. Data

The Bangladesh Household Income and Expenditure Survey (HIES) 2016 and the Meteorological Department of Bangladesh's historical monthly rainfall data for all stations from 1960 to 2015 are both used in this study.

The HIES 2016 provides a detailed module of household income, spending, and consumption, making it a nationally representative standard dataset to measure standard of living in the home. The survey's data collection, coverage, and analysis have all significantly improved over time. The HIES questionnaire also contains comprehensive modules on health and education.

The HIES 2016 selects Primary sample units (PSUs) based on the census of population and housing 2011. PSUs for HIES 2016 are the enumeration areas (EA's) used for the census of population and housing in Bangladesh where each EA is on average a cluster of 110 households. The sample frame consists of the list of all EA's covering people residing in dwelling households in Bangladesh.

The Primary Sampling Unit of HIES 2016 has been allocated at district level as the sample was stratified at district level and since there are 64 districts in Bangladesh the sample design includes a total of 132 sub-strata:64 rural, 64 urban and 4 city corporations as sampling frame does not contain Rangpur city corporation and other two city corporations ,Sylhet and Barisal as they are not much different from urban characteristics that's why BBS included only four main city corporations which were Dhaka,Chattagram,Rajshahi and Khulna. There are 36 primary sampling units allocated to each district and these PSU's were allocated across rural, urban &city corporation. Therefore, in total there will be 64*36=2304 sample primary sampling units for the survey and enumeration area which is a cluster of 110 households of population census 2011 was treated as primary sample for this design. In order to select the sample PSUs independently by district and stratum. The sampling frame was properly sorted by stratum and geo-codes. At first stage the required number of PSU's was selected using probability proportional to size systematic sampling, size measure being the number of households in each PSU.After selection of the PSU's a complete household listed in these selected PSU's was done in the field which is drawing 20 households from each PSU.So, the total sample size for the survey stands at 2304×20=46,080 households. Here we will restrict our sample to those born outside of urban areas as our factor of interest which is weather impact measured by rainfall have great effect on agricultural areas and to ensure we excluded urban areas from our research's sample size.

To accomplish our research objective which is analyze the impact of weather on welfare of households in Bangladesh here we use the HIES2016 data to get information on district level linking with historical rainfall data of all 35 stations of Bangladesh from 1960-2015 collected from Bangladesh Meteorological Department. Here we use the rainfall data by purchasing it from Bangladesh Meteorological Department following official procedure. Here rainfall variability is seen by the amount of monthly rainfall data of all-weather stations of Bangladesh from 1960 to 2015.

V. Methodology

To analysis the impact of weather on rural welfare in this study, here we follow the methodology used by (Moylan.G.H, 2012).

Household Welfare Model

In this study our objective is to measure the weather impact on welfare of households in Bangladesh, for that we here use the household level data from Bangladesh Household Income and Expenditure Survey(HIES)2016 along with historical monthly rainfall data of all 35 weather stations of Bangladesh from 1960 to 2015 from Bangladesh Meteorological Department(BMD).[1]Here weather impact on rural welfare on Bangladesh is seen through the rainfall variability as rainfall is one of the most key weather parameter in Bangladesh. To see the impact of rainfall on welfare here we used food diversity, log of per capita consumption and 3 important diseases based on the frequency of HIES 2016 data's health related chapter that people are suffered from to observe the welfare being of people.So food diversity, log of per capita consumption and health indicators are combinedly expressed welfare here.(Maccini and Yang,2009, Moylan.G.H,2012).So, here the magnitude of weather impact which is rainfall variability here in this study on household welfare is assessed by using a standard reduced form regression of welfare with the monthly rainfall variability. To estimate the weather impact by rainfall variability food diversity and log of per capita consumption on food and non-food items we use the OLS estimates on household level and to estimate the health status through the diseases like diarrhea, fever and pneumonia diseases in both rural specific and all households on some individual level considering both rural and non-rural we use the household level data and historical monthly rainfall data of Bangladesh to estimate the following two equations specifying for household levels and individual levels are given beneath:

a) **Household Level Welfare Model**

$$lnW_{h,d=}\beta_0+\beta_1 \ln R_{h,d}+\beta_2 X_{h,d}+£_{h,d} \quad \textbf{(1)}$$

here h indicates a household& d represents district, $W_{h,d}$ indicates a measure of household level welfare**, ln** $R_{h,d}$ represents log of monthly average rainfall variability, where $X_{h,d}$ represents a vector of other factors explaining the levels of consumption such as household member's characteristics and assets, and $£_{h,d}$is the error term.

b) Individual level specifying welfare Model

$$lnW_{i,h,d=}\beta_0+\beta_1 \ln R_{h,d}+\beta_2 X_{ih,d}+£_{i,h,d} \quad \textbf{(2)}$$

Here ih indicates an individual household & d represents district,$W_{i,h,d}$indicates a measure of individual household level welfare**, ln** $R_{h,d}$ represents log of monthly average rainfall variability, where$X_{i,h,d}$represents a vector of other factors explaining the levels of consumption such as household member's characteristics and assets, and $£_{i,h,d}$is the error term.

Here to construct welfare model I use food diversity as an indicator of welfare. To measure food diversity firstly I here divided the consumption of household's foods into 8 groups. The 8 food groups are- 1) Rice2) Wheat 3) Pulse 4) Animal5) Vegetables and fruits 6) Other foods and dairy 7) Otherstarches and8) Spice and Chew goods. (Moylan.G,H, 2012, Attanasio. et al,2011).

Here food diversity is measured by Shannon Index. (Moylan.G, H,2012)Shannon index is created by taking the monthly level expenditure (w_i) on each foodgroup'si and then take its log value and multiplying them and after that their sum gives the Shannon index. So, if monthly food expenditure for each food group is (w_i) and each food group is represented as i the Shannon index will be,

$$\text{Shannon index}=-\sum \quad w_i log\ (w_i)$$

The variables given below are the vectors of other factors which work as catalyst to influence the welfare being along with rainfall variability. X_{hd} used as an indication of a household head's characteristics and asset index and income index representing household's wealth and income

Control Variables

Household Member Characteristics & Consumption:

The factors which represent human capital may influence household consumption can be captured by Household size. Householdmembers considered as adult persons whose age are ranges from 19 years old to 74 years old.(Earles, J. L.,&Coon, V. E,1994,Sohel, N.et al,2009).A set of characteristics of the household head's here used includes (1) age of the household members,(2)dummy variable equal to 1 if the household member is male (3)The level of education household members received,(4)dummy variable equal to 1 if the household member is married,(5)dummy variable equal to 1 if the householdlives in rural areas,(6) dummy variable equal to 1 if the household member's religion is Muslim,(7),dummy variable equal to 1 if the household member is employed.Household members are divided into 6 age groups. Here the age group of the household heads are (1) Age between 18 to 27 (2) Age between 28 to 37 (3) Age between 38 to 47 (4)Age between 48 to 57 (5)Age between 58 to 67 (6)Age between 68 to 77.

[1] Here these datasets are purchased from the Bangladesh Bureau of Statistics and Bangladesh Meteorological Department.

Physical Capital or Assets of the household:
Here to create an asset index for the household varieties of assets are considered such as value of cattle's household owning, value of agricultural assets households owning, value of trees household's owning, value of cultivable and non-cultivable lands household are owning, value of purchased home or flats of the households', value of stocks,bonds, jewelries and other assets households' own.Asset index is created by taking the log of all asset's households' own.

Household Income:
To consider household income characteristics here we use the sources of income and includethe income of households from non-farmactivities, nonagricultural enterprises, agricultural productions of crops, trees, fish, livestock's, selling of assets, income from interest, rent,bond, lotteries, gratuities, charity/gifts etc, cash in-kind receipt and income from the remittances received. Here income index is created by taking log of all income.

VI. Descriptive Statistics
The country level summary statistics for our study is presented in the Table 1.We here showed the gender, religion and marital status, and employment characteristics of the members of the households are considered in individual level here in the summary statistics table. Where the gender, religion, marital status and employment takes the maximum value of 1 if the mentioned variables are male, Muslim, married and employed. They take the minimum value of 0 otherwise. From the age indicator it is seen that mean age is 37.038 years.Here I also define the age limit of the household members from 19 to 74 years of old. (Earles, J. L.,&Coon, V. E,1994,Sohel, N.et al,2009). The age group is divided into 6 groups taking 10 years of age gap and their mean values are presented in the Table. From the mean vales of the Table it is understandable that only 25% of the household members are belonging to the age group of 18 to 27 and in the age group of 28 to 37,14% belongs to the age group of 38 to 47,and only 8% belongs to the age group of 48 to 57, 6% belongs to the age group of 58 to 67 and only 2% belongs to the age group of 68 to 77.From the HIES survey data 2016 according to their health-related roaster data I choose some of the diseases according to their possibilityto related with rainfall in order to construct health indicator of welfare. Here diarrhea is reported 1.2%, Fever is reported 11%, in the summary statistics and other diseases like Pneumonia and Malaria"s reported percentage can be understood from their mean value.

We here take the average monthly rainfall data of station wide to see the weather impact and their mean value is 188.241 mm. To observe welfare status, here we take the total consumption value into household level and mean value of this consumption is 19482.7 taka. Also, the mean values of total income and expenditures are 248825.8 taka and 16036.3 taka. Their values are taken in logarithm's too whose mean values are presented here in the table. To see the welfare being of the household's I considered some variables among them one of the key important variables is food diversity which is measured by Shannon index. Shannon index is created by taking the monthly level expenditure (w_i) on each food group such as i and then take its log value and multiplying them and after that their sum gives the Shannon index. So, if monthly food expenditure for each food group is (w_i) and each food group is represented as i the Shannon index will be, Shannon index= $-\sum \quad w_i log\,(w_i)$ .The mean value of the Shannon index is (0.54).Here the households are taken into country level specifying by taking the dummies of being rural=1 and 0, otherwise. The summary statistics table is given in the next page:

Table 1: Summary Statistics:

List of the variable	**Mean**	**Std. Dev**	**Minimum**	**Maximum**
a) Individual level				
Gender (Male=1,0=otherwise)	0.3383	0.4731	0	1
Religion (Muslim=1,0=otherwise)	0.8675	0.3389	0	1
Marital Status (Married=1,0=otherwise)	0.8205	0.3837	0	1
Employment (Employed=1,0=otherwise)	0.3579	0.4794	0	1
Education	6.2322	3.7842	0	19
Age	37.038	13.577	19	74
Age between 18 and 27	0.2580	0. .4375	0	1
Age between 28 and 37	0.2591	0.4381	0	1
Age between 38 and 47	0.1416	0.3486	0	1
Age between 48 and 57	0.0868	0.2815	0	1
Age between 58 and 67	0.0669	0.2498	0	1
Age between 68 and 77	0.0279	0. .1648	0	1
Diseases				
Diarrhea	0.0120	0.1092	0	1
Fever	0.1124	0. .3159	0	1
Malaria	0.0017	0. .0416	0	1
Pneumonia	0.0001	0.0129	0	1
b) **Household Level**				
Total Consumption	19482.7	19262.2	990.75	815049.6
Total Expenditure	16036.3	89486.7	0	6037517
Total Income	248825.8	1657179	0	1.45e+08
Total Asset	9274.89	55217.9	0	1833334
Logarithm of Asset	7.925745	1.770	-1.791	14.4216
Logarithm of income	10.622	2.2183	0	18.7916
Logarithm of expenditure	8.406	1.5958	-1.791	15.613
Logarithm of consumption	9.646	0.6405	6.898	13.611
Monthly total Food expenditure	97.636	154.347	4.5428	12160.71
Shannon Index	0.5425	0.1802	0	0.6931
Household size	4.668	1.715	1	17
Rural (Dummy: Rural=1,0=otherwise)	0.6873	0.4635	0	1
c)Station wide				
Monthly average rainfall	188.241	74.010	0	661.25
Log of monthly average rainfall	5.16786	0.3709	0.8329	6.494

VII. Results and analysis:

i) Logarithm of per capita consumption (Household Level Analysis)

The Table 2 given on the next page represents the ordinary least square estimates of log of household per capita consumption. Here Consumption includes all the food and non-food expenditures. To find out the log of per capita consumption of households' total consumption of households is divided by the household size and then takes log of it. The first significant and striking result is expected, which is the log of per capita consumption is positively related withmonthly average rainfall and with 1 unit of increase in rainfall causes the log per capita consumption to be increased by 1.45 unit in the parsimonious regression considering limited independent variables and 93% increase while considering full set of control variables. Same regression is also estimated for rural specific households where the log of per capita consumption is significantly increased by 1.44 unit and in full set of regression. log of per capita consumption is increased by 0.91 unit due to 1 unit increase in rainfall. In all households considering both rural and non-rural household's estimation increase in household size decreases per capita consumption by 8% and 5% respectively for both sets of regression where it decreases household log of per capita consumption by 8% and 5% respectively for rural households at both sets of regression. The value of these coefficients is significant at $p<0.01$. The relationship of age of the household member's, marital status is positively related with log of per capita consumption. Another significant result is that level of education's increase in 1 unit causes the log of per capita consumption to be increased respectively by 6%,3%,6.6% and 3.8% respectively for all households and rural specific households parsimonious and full specific regression at $p<0.01$.The log of income increased the log of per capita consumption by 11.4% at $p<0.01$ for all households and for rural specific households it increased by 11.7% at $p<0.01$. One unit increase in log of assets increased the log of per capita consumption for all and rural household respectively by 9% and 8%. Another significant result is employment status of household head which is negatively related to log of per capita consumption for both sets of regression at rural and all household levels. We also conducted regression on considering gender-education term and age^2 in the appendix at table no A1.

Table 3: Impact of rainfall on household's consumption and food diversity

	Dependent variable:			
	Consumption		Food Diversity	
	(1)	(2)	(1)	(2)
Log of rainfall	1.457***	0.938***	0.092***	0.057***
	(0.039)	(0.006)	(0.0007)	(0.0016)
Household Size	-0.050***	-0.0845***	-0.002***	-0.0034***
	(0.002)	(0.002)	(0.0004)	(0.0005)
Gender	0.128***	0.084***	0.003**	-0.0012
	(0.006)	(0.010)	(0.0016)	(0.0029)
Education	0.066***	0.0361***	0.003***	0.002***
	(0.0009)	(0.0009)	(0.002)	(0.00024)
Other control variables	Yes	Yes	Yes	Yes
Observations	46000	46000	46000	46000
Adjusted R2	0.330	0.560	0.393	0.687

Note: *p<0.1; **p<0.05; ***p<0.01

ii) Food Diversity (Shannon Index) (Household Level Analysis)

From the OLS estimates of the regression Table 3 given in below it is seen that food diversity which is measured by Shannon Index. The striking result is while taking parsimonious regression for all households and rural specific households increase in monthly average rainfall increase the food diversity of householdsby 9% at (p<0.01). While taking the full specific regressionthroughout the control variables it increases at 5% with the rainfall at p<0.01. But household size is significantly negatively related with food diversity in both parsimonious and full set of regression where 1 unit increase in household size decreased the food diversity index respectively by ,0.2% and 0.3%.The level of education and food diversity index is positively related for all households and rural households and this is significant for both parsimonious and full specific regression for all households and rural households. Where else, for all households log of assets and income is positively related with food diversity and this is significant for all households which expressed 1 unit increase in log of asset which increased the food diversity by .6% at p<0.01 for all households and rural households. Another result is found that log of income and food diversity are positively related and their coefficient values are significant according to their p values. We also conducted regression on considering gender-education term and age^2 in the appendix at table no A2.

iii)Individual Level Specification at individual level on health indicators

i) Diarrhea

To measure the health indicator as an element of welfare we here take three diseases from the HIES 2016 survey's health roaster data according to possibilities to relate with weather variability which is measured here by monthly average rainfall and take logit regression of those diseases. From the Table 4 it is seen that log of monthly average rainfall decreases the possibility of household members being affected by diarrhea by 74% and75% in full specific regression for all households and rural households at p<0.01. While taking parsimonious regression the probability of diarrhea decreased by .69-unitor 50% for 1 percent increase in monthly average rainfall for all householdsandrural household levels. Here these coefficients values are significant at p<0.01. For household size increase of 1% in all sets of parsimonious and full specific of regressions both rural and all households' probability of diarrhea decreased approximately by 49% and 56% these coefficients are statistically significant unexpected result is found from the age group of both rural and all household levels parsimonious and full set of regression that probability of diarrhea is negatively related with age although by the increase in age groups the probability increased .[1] For educational status it is negatively related with the probability of diarrhea meaning that 1 percent increase in the level of education decreased the probability of diarrhea for all household

[1]The reported coefficient of regressing rainfall on diarrhea in column 1 is -0.689. Taking antilog of this number gives the value 0.502.Hence interpretation of coefficient of logit (regressing diarrhea on log of average rainfall) is: 1 percent increase in monthly average rainfall is likely to decrease diarrhea by about 50%.Also the reported coefficient of regressing household size on diarrhea in column 4 is -0.577,taking its antilog equals to 0.561.For that the interpretation is 1 percent increase in household size reduces the probability diarrhea by 56%

by .03 unit in parsimonious and .02 unit in full specification regression though here the coefficient is significantly related and for rural specific household's its probability decreased by .026 unit in full specific regression where the coefficient is significant at $p<0.05$. Here the log of income is negatively related with the probability of diarrhea at both level though the coefficients are insignificant. Also, here it is seen that the negative relation of log of assets and probability of diarrhea though the coefficients are insignificant. We also conducted regression on considering gender-education term and age^2 in the appendix at table no A3.

(ii)Fever:

The probability of fever is negatively related with the monthly average rainfall as increased in 1 unit of log of monthly average rainfall decreased the probability of fever by largely about 72% and 86% respectively in both parsimonious and full specific regression for all households on the other hand it decreases the probability of fever by 0.331 and 0.869 unit while taking both parsimonious and full specific regression for rural household level. These coefficients are significant.[1] The reason of this may be that the increase in rainfall brings equilibrium in the the excessive temperature which causes fever. Also, here from the logit table given below it is seen that 1% increase in education decreased the probability of diseases also the increase in log of assets and income decreased the probability of this disease as they are negatively related and also their coefficient values are statistically insignificant. For the members of the household's probability of this disease decreased if the household member is being male.

(iii)Pneumonia:

From the logit estimates table it is surprising to see that at parsimonious set of regression for both rural specific households and all households increase in monthly average rainfall decreased the probability of pneumonia by 34% and 35% respectively at $p<0.01$and at full set of regression their relation is negative too but coefficient values are significant at $p<0.05$.[2] For household size it is negatively related and increased in household size decreased the probability pneumonia at both rural and household levels of parsimonious and full specific regression by .08 unit,.084 unit,0.0521 and 0.0578 unit.Household members probability of being suffered by pneumonia for all sets of regression in all households and rural households is reduced if they are married. Age is also significantly negatively related with pneumonia andalso for both rural and all household level probability of pneumonia decrease by 0.06 and 0.056 unit due to 1 unit increase in log of income respectively. Log of assets is and employment status of household members is negatively related with probability of pneumonia but their coefficient values are insignificant.

Table 4: Impact of rainfall on the probability of an individual being affected by diseases.

	Dependent variable:					
	Diarrhea		Fever		Pneumonia	
	(1)	(2)	(1)	(2)	(1)	(2)
Log of rainfall	-0.689***	-0.294***	-0.324***	-0.1443***	-1.05***	-0.668**
	(0.037)	(0.087)	(0.0134)	(0.0272)	(0.088)	(0.265)
Household Size	-0.07*	-0.059*	-0.049***	-0.0285*	-0.084	-0.057
	(0.0262)	(0.0305)	(0.008)	(0.0103)	(0.058)	(0.0639)
Gender	-0.126	0.0323	-0.105***	-0.182***	-0.363	0.1555
	(0.086)	(0.156)	(0.0288)	(0.049)	(0.235)	(0.445)
Education	-0.0389***	-0.025*	-0.0249***	-0.0251***	-0.0609*	-0.0287
	(0.0118)	(0.0138)	(0.0035)	(0.004)	(0.031)	(0.0432)
Other control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	46000	46000	46000	46000	46000	46000
Adjusted R2	0.530	0.780	0.473	0.757	0.533	0.857

[1] The reported coefficient of regressing rainfall on fever in column 1 is -0.324 Taking antilog of this number gives the value 0.72. Hence interpretation of coefficient of logit (regressing fever on log of average rainfall) is: 1 percent increase in monthly average rainfall is likely to decrease fever by about 72%

[2]The reported coefficient of regressing rainfall on pneumonia in column 1 is -1.05. Taking antilog of this number gives the value 0.349. Hence interpretation of coefficient of logit (regressing pneumonia on log of average rainfall) is: 1 percent increase in monthly average rainfall is likely to decrease pneumonia by about 34%.

VIII. Conclusion

Rural areas of developing countries of the world vastly depends on agriculture sector where weather plays an important role to influence the welfare status of households. Here in our study we have used the data from Bangladesh Household Income Expenditure Survey 2016 to observe the welfare status of households and rural specific household's through food diversity,(which is measured by Shannon index)log of per capita consumption and health status of household members considering three diseases which are diarrhea, fever and Pneumonia diseases. Here we estimate those welfare indicators by regressing them with log of monthly average rainfall data and vectors of households' characteristics like households' size, household members' age, religion, marital status, employment status, and asset index. The objective of our study is to find the impact of weather variability which is measured by rainfall variability on household welfare. One of the most important key findings of our work is that, log of per capita consumption significantly increases with the increase of log of monthly average rainfall. Here log of per capita consumption increases with the monthly average rainfall for all households and rural households in both parsimonious and full specific regression. This indicates that rainfall helps to improve agricultural production that may bring solvency in household's economic status. Here the log of per capita consumption increased with monthly average rainfall in all household level at 0.93 unit and rural household at 0.91 unit.

Another key finding of our study is the increase of food diversity which is measured by Shannon Index is due to the positive relation of log of monthly average rainfall. Here this relation is significant for all households' and rural households in parsimonious regression and rural households. This indicates that rainfall improves food securities by helping agricultural production. Here the food diversity increased with monthly average rainfall in all household level and rural household level by 9%.

Other important findings of our study are probability the disease of significantly decreased with log of monthly average rainfall. For rural level of household in parsimonious regression the probability of these diseases decreased significantly with log of monthly average rainfall. Rainfall has positive impact on reducing the probability of these diseases greatly in rural specific households along withall households. Probabilities of diarrhea, fever and pneumonia decreased with monthly average rainfall by 0.69 unit,0.34 unit and by 34-35%. So, this paper, clearly shows the impact of weather on rural welfare by using rainfall variability as weather factor. From the analysis it can be drawn that weather has significant influence on rural welfare.

IX. Limitations of this study and Future work

Though our study provides an important analysis of weather impact on rural welfare there exists some research gap. In our study weather impact on welfare can be more significant if we use weather shocks by rainfall deviation but in our study it is not possible with our data sets of rainfall as we merged the rainfall data of 35 stations with 64 districts household level's data where there for many districts was rainfall data was unable to use as there is no station available there. This problem can be solved if we use the "GIS" software to measure the distance of nearly rainfall stations of the districts where there is no station but it was not possible to operate by ourselves here. Also, it would be great if we use seasonal effect like the research done by Maccini and Yang (2009) but it is not possible due to our dataset of household level don't contain the data of birth month of household members and without the seasonal effect can't be shown. Apart from this it is a cross-sectional study where panel study will give more robust and significant outcome which cannot be done due to time constraints. Despite of these lacking in my paper, it still provides the preliminary analysis and base for future researches to work on similar issues. This research contributes to the body of literature by showing the positive impact on weather on per capita consumption and food diversity. This paper also shows the impact of weather on several diseases like diarrhea, fever and pneumonia where rainfall increases significantly reduces the probability of these diseases. By using "GIS" software weather shocks can be seen by using rainfall deviations by considering rainfall data of all stations also this paper gives the scope for other researchers to work with same concept using temperature variability instead of rainfall variability.

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