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Estimating the Fixed Effect of Climate Friendly Low-Cost Technology in Wheat Crop in the Rural Nepal

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Abstract

Experiencing climate induced water stress in crop cycle and pattern in the different elevation in the Himalayan country, Nepal as a reflection of the 4th ranks climatic worst-hit country, food crops are identified as a highly exposed and sensitive to climate change. This study examines the fixed effect of low-cost technology and climate induced water stress on wheat crop in the steep elevation hilly areas in Nepal. Using the cross-sectional data collected from the survey of 642 households in the water basin areas, the study employs Cobb Douglas (CD) production econometric model. In the steep elevation, raising average temperature per annum (c0y-1) in summer and winter seasons and declining average rainfall per annum (Rmy-1) in winter and increasing in monsoon season have resulted multiple hazards, flood and landslides particularly in monsoon season rather than winter season. Secondly, like paddy crops, wheat crops were highly exposed to temperature and rainfall and further disastrous. As the fixed effect of climate induced water stress and flood disaster, large and small wheat producers have lost on average 40 percent of total production per hectare in one crop cycle. However, as a treatment group with indigenous low-cost technology, 60 percent of small farmers who used two techniques- shifting flood resilient seeds and constructing local bamboo wall could save 9 percent of their crops and production preventing the force of flood, loading heavy sediment of sand and stones at negligible cost. Low-cost local technology can minimize climate induced flood disaster's adverse effects and losses in wheat crop in rural areas in Nepal. It is friendly to small farmers living in the socio-economic vulnerable and subsistence. This result of the study will be a good lesson learnt and valuable input to the farmer to resolve widely climate induced flood disaster stress through low-cost local technology for improving their preparedness and resilience to some extent. Further, it would be a valuable input to local and national government to focus on low-cost local technology more than high-cost advanced technology for sustainable farming policy and practices. Furthermore, it is expected it would save crops for reducing food vulnerability and stress in the steep elevation for food security and welfare all over a year. .

Keywords: *Climate Change, Small Plot, Indigenous Farmers, Adaptive, Wheat Production, Hilly Nepal.*

Introduction

Growing the intensity of climate stress as the high exposure of farm and non-farm activities and livelihood of the people is an emerging issue in the world in recent times. IPCC (2018) reveals more than half of the world population is under this stress. Main climatic factors of this stress are global warming with increasing mean temperatures more than in the pre industrial period and is declining rainfall in monsoon and winter seasons discharging water system of the world, along with deforestation and degradation of land and extreme race of production led growth and consumption led higher livelihood and welfare (IPCC, 2001 & IPCC, 2018). This stress may magnify unpredictably in the prediction of increasing mean global temperature per annum by 0.7^{0}c in the future (Eliashch, 2008) and the growth of annual temperature by 2^{0}C-3^{0}C in the next 50 years (Stern, 2006). The supplementary factors and dimensions are degradation and deforestation of land, lower productivity and production of agriculture, water scarcity, limitation of livelihood, economic losses, and higher human migration. While in the mean temperature rising, increasing forest fire cause degradation and deforestation of forest land and damages the territorial ecosystem, oxygen cycle and water cycle. As a result, water scarcity and the limit of livelihood opportunities may be extreme. Its negative implication falls on agricultural productivity and production. Similarly, economic loss of climate change induced disasters (flood and landslides) is approximately 5 percent of Global GDP. The share of developing countries is more than of developed countries (Stern, 2006, & UNFCCC, 2018). South Asia had the severity of GDP loss, human displacement, and climatic migration. In 1995, its severity was nearly 7 million people in India and 15 million people in Bangladesh (Nicholl, Leatherman, K.C. and Volonte, 1995). In 2016, human displacement was around 23.5 million people in Bangladesh. In the next 2050, human displacement will be one in every seven people in Bangladesh in the loss of 11 percent land due to the growth of 50 cm sea rise (https://ejfoundation.org/reports/climate-displacement-in-bangladesh). African countries are also

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vulnerable. Thus, the growth of climate stress will be critical to the large population of African and Asian countries (Stern, 2006).

Studies (Mool, Bajarcharya, and Joshi, 2001a, Chalies & Khanal, 2002, CBS, 2011, and Bista, 2018) supplement the extreme climate stress in Nepal too, like in South Asia. The extreme climate stress has direct and indirect dimensions in which CBS (2011) and Mool, Bajarcharya, and Joshi (2001a) argue the variability of mean temperature from 0.4^{0}C to 0.6^{0}C and of mean rainfall induces multiple disasters (landslide, drought, cyclones, glacial outburst, and flooding) This climatic variation and inducement have created direct climate stress for most people in the country. The indirect dimension is the result of climatic disasters across the country. the last five decades, the frequency of flooding has been annually incremental. In the previous decades of s and 1990s, Glacial Lake outburst floods (GLOF), namely Dudh Khosi GLOF 1985, Tamakhosi GLOF 1991, and Dudh Khosi GLOF, 1998 were disasterous in terms of economic losses (Mool, Bajaracharya and Joshi, 2001a). The economic losses were the destruction of the Namche hydropower plant and several bridges, along with the loss of valuable life (Chalise and Khanal, 2002). Similarly, non GLOF were Nakhu Khola in 1981, Bagmati and Narayani in 1993, Andhi Khola in 1998, and Bagmati in 2002 (Chalise and Khanal, 2002). In the decade of 1990s, Bagmati flood in 1991 encroached all the agricultural land in Le Le VDC and cleared more than 48 houses and seven water turbines and but also killed twenty-seven people. In 1993, Bagmati and Narayani flood fully and partially affected 28,000 families in the middle mountains and 42,000 families in the lowlands (Chalise and Khanal, 2002). About 1000 people were killed during that climactic event. In 1996, the Larcha debris flow washed away physical infrastructure including roads, bridges, and transmission lines, along with 18 houses. Floods of a smaller scale of less disastrous, but still considerable, impact occur annually to several locations (Chalise and Khanal, 2002). Including dead, missing, damage, loss of asset, death of livestock, mean economic loss per annum is 2000 million rupees (CBS, 2011). Therefore, the extreme climate stress has become a threat to national and local economy, despite the execution of NAPA and LAPA.

A query is whether this national context of climate stress is different at the local context of the western Nepal or not. Studies (Malla, 2008, Acharya, 2012, and Karn, 2014) reveal like the national context of climate stress with the evidence of 1.2° C mean temperature rising within the last 36 years (1975-2010). This local climate stress is three times more than mean national temperature rising and two times more than mean global temperature (Stern, 2006, IPCC, 2001 and IPCC, 2018). In indirect dimension, (Dahal, Hasegawa, Nonomura, Yamanaka, Dhakal, and Paudyal, 2008), (Malla, 2008) and Karki, Shrestha, and Winiger (2011) notes like the national climate stress in climatic disasters. Studies (Bista, 2019, Malla, 2008, Karki, Shrestha, and Winiger, 2011, Pant, 2011, Bhandari, 2013, and Karn, 2014) supplemented with its critical adverse effects in agriculture. However, none of these studies have covered specifically climate stress in wheat production and local adaptation alternatives of wheat farmers. In this context, this study aims to measure climate stress in wheat production in the limitation of local adaptation alternatives in the Sotkhola River Basin (SRS).

This paper is organized into four sections. The first section is an introduction in which the previous studies are reviewed into three groups: climate change, its loss and vulnerability, and agriculture. The second section carries objectives (Mansoor et al., 2024). In the third section, the analytical framework, model, nature of data, and data collection method are presented. Finally, the results of the study with discussion and conclusion are highlighted.

Objectives

The overall objective of this study is to measure climate stress in wheat production and farmers in Nepal. Specifically, the study aims to understand climate stress in wheat production and farmers, to analyze wheat farmer's adaptation capacity and behavior against climate stress in the study area, and to identify policy issues and implications to make effective wheat production policy and climate resilient policy to increase wheat production and productivity.

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Methods

Analytical Framework

Different production function theories are relevant to capture climate stress, and farmer's adaptation. In these theories, Cobb Douglas's (CD) production function is highly relevant to capture these issues because the production function represents a technological relationship between the amounts of two or more inputs (physical capital (K) and Labor (L)) and the amount of output that can be produced by those inputs(Y). Its functional form is

$Y = A K^{\alpha} L^{\beta}$……………………………………………………………………..(i)

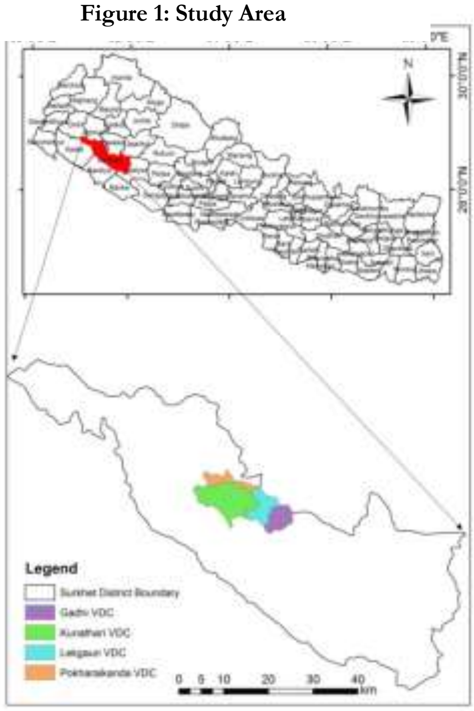
Where Y= output, A= technological factor (productivity factor), K = physical capital, L = labor,

α and β =output elasticity of physical capital (K) and labor(L)

The function (i) has three returns to scale: a) constant returns to scale refers to how much input is employed so much output is received. $a + \beta = 1$; b) decreasing returns to scale refers to how much input is employed less output is received; c) increasing returns to scale refers to how much input is employed more output is received.

Study Area, Socio-Economic Characteristics & Climate Stress

Figure 1: Study Area



The study area was Sotkhola water basin (Figure 1). It is in Surkhet district in the western Nepal 500 kms far from Kathmandu. In the Surkhet district, this water basin is situated in the Sotkhola River as one of the tributaries of Bheri River (Figure 1). In the hydrological map, the length of the river is 30 km starting from Chandane, Gadhi VDC and ends at Rakseni, Kunathari VDC (Figure 1) (DDC, 2015). Having consistent water level at both monsoon and winter seasons, this basin spreads in the three catchment areas: Gadhi VDC (Upper stream), Lekhagaon VDC (middle stream), and Kunathari VDC (downstream) (DDC, 2015). a) Gadhi is the upper catchment area lying at 1200-meter altitudes in the Mahabharata Range (Figure 1). Physiographical size is 28 square km. Demographic size is 3369 population. Interesting fact is demographic caste diversity with Magar (37.7 percent), Brahmin (30.6 percent), Cheetri (17.1 percent), Sunwar (5.7 percent), and others (22.6 percent). Others include Kami, Sarki, Thakuri, Gurung, Damai, Sherpa, etc. (VDC, 2015). b) Lekhgaon is the middle catchment area lying in the range from 198 meters (Tata pani) to 2369 meters (Matela gurase) altitudes (Figure 1). The area spreads 110 km in length and 30 km breadth of 2451 square km (249016 hectares). In the landscape, hills dominate with 84 percent to 16 percent valley. The population size is 3999 (651 households) with similar diversity of caste and community (DDC, 2015). c) Kunathari is the downstream catchment area lying in the range between 600 meters and 1200 meters (Figure 1). The area is 20 km far from district headquarter. Population size is 3413 with similar diversity of caste and community (CBS, 1991 & DDC, 2015).

This water basin is a lifeline of these three catchment areas across three ecological belts for clean drinking water, irrigation water, and recharging underground water systems, and aquatic and territorial ecosystems for the livelihood of the people. The climate stress basin was due to exposure in unpredicted and unusually

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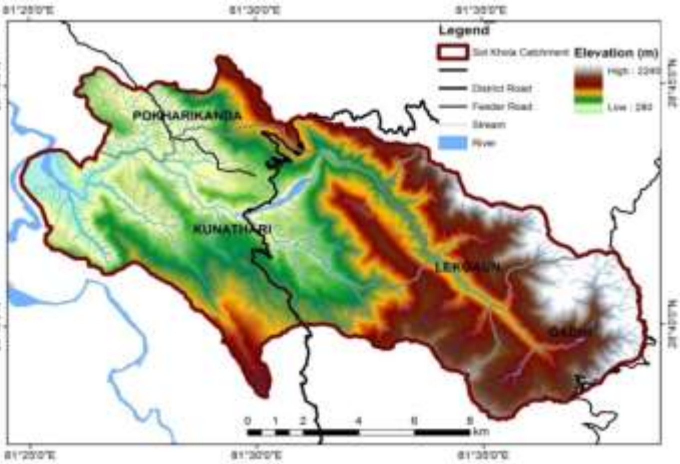
heavy rainfall and destructive multi-hazards (1 flood and 29 landslide disasters) with heavy economic losses of morphological and physical structures (houses, bridges, canals, pipelines, and roads) in 2014 (DDC, 2015). The agriculture sector lost 66 percent of crops and 34 percent of livestock losses. Its loss value was about Rs. 18,464,427 (18.4 million rupees). About 69 percent of households were vulnerable. Such multi-hazard had a huge cost of more than 30 million Rupees (DDC, 2015). This was the reason behind the study area. Besides, the study area was relevant to examine climate stress and farmer's adaptation, particularly in wheat production across the elevation and landholding of farmers. This explore policy issues and ideas to improve climate-resilient policy, adaptive capacity, and behavior of farmers and wheat production system. Further, its outcomes would lead to an increase in farm revenue through adaptation options and to improve food sufficiency, livelihood, and poverty reduction.



Source: Field Survey, 2020

Data Sets

We used primary data set for this study to understand climate stress and farmer's adaptation in wheat production and to find out the level of climate stress and response of farmer's adaptation to minimize loss of climate stress. Using four groups questionnaire survey tool including socio-economic information, climate stress, adaptation of farmers, issues, and suggestions, the study conducted household survey in the basin (Gadhi VDC, Lekhagaon VDC, and Kunathari VDC) from September 2020 to October 2020. The survey tool was pre-tested in Kathmandu when the enumerators were oriented about the research question, method of data collection, the sample size, and the questionnaire.

The sample households were 642 of 3310 total households of the basin. We used stratified sampling method to select households in the study area. At first, the basin was divided into nine clusters based on altitude, location, and place. Secondly, the sample households were divided into nine clusters for proportional representatives. Thirdly, the random sampling method was employed to select the sample households within each cluster to minimize biasedness, selective errors, validity, and reliability issues.

Modeling

The multiple regression model was based on CD-production function to capture climate stress in wheat production and farmer's adaptation to minimize cost of the climate stress. The CD-production econometric model captures the relationship between revenue as output and input variables as predicators. In input variables, there are non-categorical and categorical variables. The non-categorical variables include labor, land, seed, and fertilizer of wheat production, whereas categorical variables include climatic disasters, adaptative shock, and area to capture the impact of climatic stress and adaptative shocks in wheat production.

Let us suppose total wheat revenue is Y_{wr} which is produced by four VDCs including Gadhi(D_2), Lekhagaon(D_3), and Kunathari(D_4) in the corridor of Sot Khola as Area Dummy of this C-D Production function is produced by using four inputs including labor (L), land (L_a), fertilizer (F) and Seed(S). Here, labor unit is a number used. The Land unit is *Katha*. The fertilizer unit is *KG*. Seed is in Kilogram. The agricultural income (Y_{wr}) is made *unstable* by climate shock (flood and landslides). It is denoted by D_0 that is yes=1(flood), no=0(other: landslides). To make stable such revenue, farmers have used two adaptation activities (D_1) having 1= wall construction, 0=others (seed change and removing sediments) as a dummy. Areas dummies –D_2 having 1=Gadhi and 0=others, D_3 having 1=Lekhagaon and 0=others, and D_4 having 1=Kunathari and 0=others. Standard deviations of these variables from the mean are not so far significant.

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The mean of these variables represents properly household data collected from primary sources. There are eight estimators: β, β_1, β_2, β_3, β_4, β_5, β_6, β_7, and β_8. Its regression form C-D Production Function (Equation-ii) is as follows.

$$\ln Y_{wheat} = \beta + \beta_1 \ln X_{1nl} + \beta_2 \ln X_{2Laag} + \beta_3 \ln X_{3fer} + \beta_4 \ln X_{4se} + \beta_5 D_{0clsho} + \beta_6 D_{1adsho} + \beta_7 D_{2Ga} + \beta_8 D_{3lekh} + \varepsilon \quad \text{............(ii)}$$

Results and Discussion

Climatic Stress at the study area

Measuring climate stress is a big issue to the vulnerable population in developing countries. This measurement lies in three levels: a) extremity, b) moderate, and c) low. These results come out from three measurements: a) aggregate movement of climatic variables, b) realization of changing climate, and c) cost of climatic stress and climatic disasters.

Measure 1: aggregate movement of climate variables

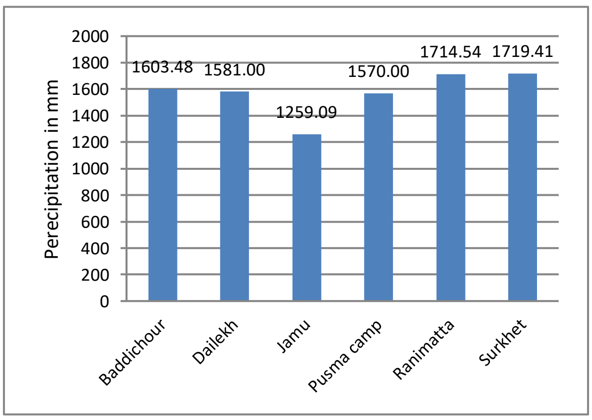
In climate variables, temperature is a key one. The mean temperature of the water basin is based on the real time temperature data recorded in six DHM stations in the study area. The trend of mean temperature was increasing more than mean national temperature data and mean global temperature. It is notable.

Rainfall and precipitation are another key variable. In the local people's assumption, rainfall and precipitation are the local areas' main water-to-water system source tends more in the monsoon season than the remaining seasons, particularly winter. Indicators of natural rainfall and precipitation are regular pattern, natural intensity, distribution, and seasonal friendliness. By chance, rainfall, and precipitation in monsoon do not meet such assumptions and indicators, changing rainfall and precipitation's pattern, in pattern, intensity, and distribution of rainfall and then stress to the people in the local area for economic activities. Its details are in figures.

Rainfall and Temperature

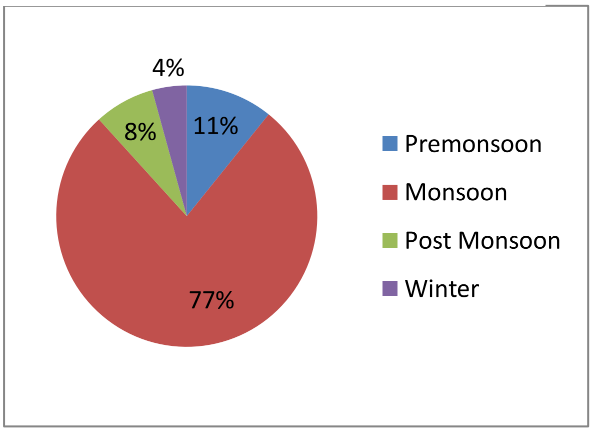
Climatic variables: rainfall and temperature relate to the catchment households in the Sot Khola water basin. Historical experience and information about rainfall and temperature variation are collected during the case study for data validation and cross-checking and referencing. Focus Group Discussion (FGD) of mixed participants ((illiterate and literate, young and old age, male and female, social ial activist, and political representative) is employed to measure their level of knowledge about climate change and its variables. All are interestingly familiar with these terms and their meanings. In a Key Informant Interview (KII), former chairperson of Gadhi VDC explained changing

Figure 3: Average Rainfall of the study area



Source: Department of Hydrology & Metrology, 2020

Figure 2: Seasonal Precipitation of the study area



Source: Department of Hydrology & Metrology, 2020

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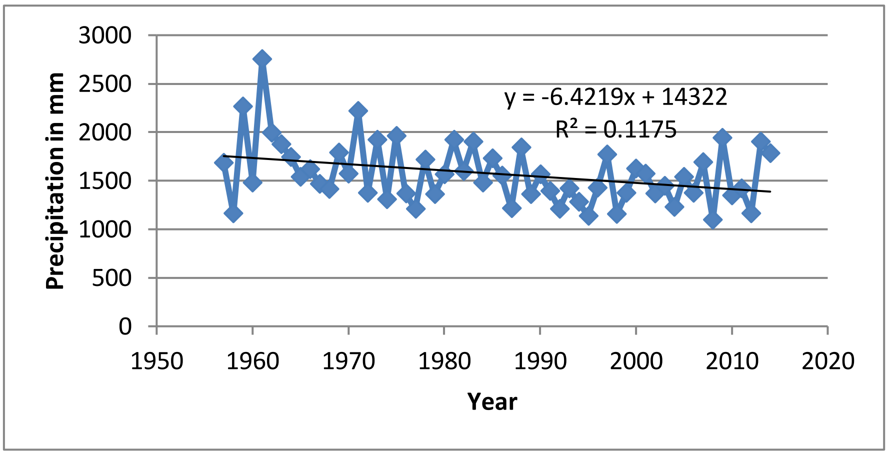
temperature and rainfall's duration and coverage. He told his first memory of changing rainfall in which rainfall duration was weeklong before 15 years ago. Its duration is shortened to two days and three days long. However, its intensity and erratic character are more than before. Disasters are more common than before. Similarly, he explained about temperature. This place is at an an altitude where the mosquitoes cannot survive because of low temperature. Now, the mosquito has been found. He used mosquitoes as a measure of temperature rising. Pingle, Damar, and Ranimate communities have validated such climate change.

Scientific data and information about temperature and rainfall provide supplementary evidence about climate change. At less than 2100 m altitudes, two climates: warm temperate and subtropical monsoon climate and four distinct seasons to precipitation; pre-monsoon (Mar, April, and May), Monsoon (June, July, August, and September), Post monsoon (October and December) and winter (December, January, and February) (Figure 2) are identified. In the watershed, the average annual rainfall is about 1551.06 mm of which 77 percent of total rainfall (323.02 mm) occurs during monsoon season and the remaining 33 percent during the rest of the year, of which 8 percent during the post-monsoon, 11 percent during pre-monsoon and 4 percent in the winter (Figure 2). The average monthly precipitation shows that July gets the maximum amount of rainfall (425.55mm) and December gets the lowest amount of rainfall (10.33 mm).

Figure 4: Precipitation of the Study Area



Source: Department of Hydrology & Metrology, 2020

In winter, rainfall has a decreasing trend whereas, in summer, rainfall has an increasing trend. In the catchment areas, rainfall is intense and erratic at the maximum amount (1719.41 mm) of rainfall of all stations (Figure 3). Figure 4 shows the average trend of precipitation over the watershed has a decreasing trend with the rate of 6.42 per year (Figure 4). It argues the increasing trend of temperature. Thus, climate change occurs in the Sotkhola water basin and its catchment areas.

Measurement II: Climate-induced Disasters: Flooding and Landslides

Figure 5: Flooding and disasters in the catchment areas

Figure 6: Landslides patches of the catchment areas
Source: Field Survey, 2020

Figures 6 and 7 show climate (rainfall) induced disasters in the catchment areas of Sot Khola water basin in 2014: flooding and landslides due to erratic and heavy rainfall in the upstream (Ratomate, Gadhi). This small stream was unexpectedly destructive roaring to its banks: agricultural land and crops, road, clean drinking water, bridge, and building. Rainfall induced landslides too in its catchment areas.

The Sot Khola seems to be a small stream having many small rivulets as tributaries (Figure 6), most of which are intermittent but

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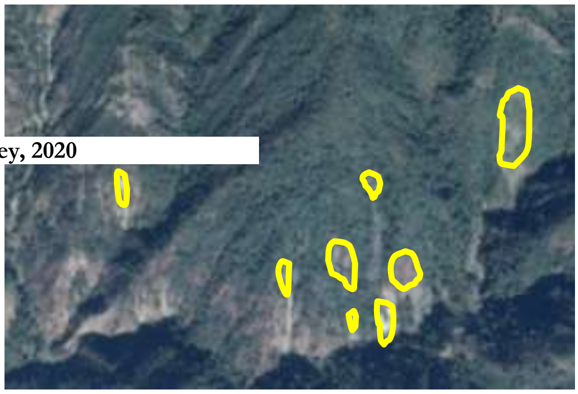
downward flowing with high speed and high sound. Flood risk analysis identifies its 83 small rivulets having 86 points flood disaster risk (Figure 6). However, there are no human settlements in the corridor of the river, except fertile land. As such, detailed flood risk analysis of each micro-watershed is not warranted.

Similarly, Figure 7 shows erratic rainfall-induced 29 landslides disasters in 2014. Out of 29 landslides, figure 7 identifies highly vulnerable locations such as 11 locations in Lekhagaon, 10 locations of Gadhi, and 8 locations in Kuathari. Dynamics analysis of landslides displays Lekhagaon is more vulnerable to VDC than Gadhi and then Kunathari.



Source: Field Survey, 2020

Measurement III: Cost of Climate Stress and Climatic disasters in Agriculture

Figures 6 and 7 depict two major vulnerabilities in agriculture: bank cutting and sedimentation and soil erosion and sedimentation.

Bank cutting and sedimentation

In Figure 6, bank cutting at 86 points of the fertile land and loading sedimentation inside the fertile land in the flooding in Sotkhola water basin are identified in the corridor of the river: lower ratomate, bodichure, Finikada, and Raksheni. The flood encroaching 30 to 50 meters inside in the fertile land has covered its length from 1000 meters to 5000 meters. In the watershed area, the fertile land loss is about 78.85 Bigha (10.54 hectare) out of which its distributions are 7.39 Bigha (0.98 hectares) at Ratomate, 44.29 Bigha (5.92 hectares) at Bodichure, 18.45 Bigha (2.46 hectare) at Finikada, and 8.85 Bigha (1.18 hectare) at Raksheni. Its negative consequences and exposure are severe in agriculture, particularly in two crops: paddy and wheat.

Soil Erosion and Sedimentation

Heavy Rainfall intensity induced landslides in a terrace and steep lands. Figure 7 shows 29 landslide patches in the watershed areas in which 11 locations of Lekhagaon VDC, 10 locations of Gadhi, and 8 locations of Kunathari are identified. Each location lies in the range from 100 m to 1000 m in length and from 50 meters to 200 meters wide. In these disasters, there is soil erosion and sedimentation. Thus, fertile land has lost top fertile soil with higher fertility power, while sedimentation has covered it. Thus, there is not only risk in production but also settlement and forest areas. Its negative consequences led to land changes into desertification and loss of houses and crops.

Adaptation Capacity and Behavior in Agriculture

UNFCCC (2007) has mentioned different adaptation options, practices, and behavior in agriculture. They are i) Knowledge and assessment, ii) Early warning system, iii) Wall construction, iv) Removing sedimentation and reclaim land, v) Irrigation facility, vi) Using water-efficient crop seed and vii) Crop insurance. Out of these adaptation options, wall construction, shifting seeds, and irrigation facility in

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agriculture, particularly wheat production is identified as adaptation options and practices in the watershed area in Household Survey and Focused Group Discussion (FGD).

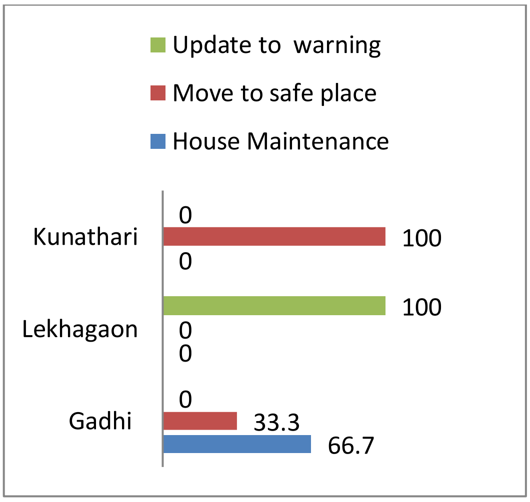
Farmer's Adaptation Activity and Behavior in Agriculture

Farmers, despite being poor, marginal, and illiterate have heterogeneous adaptive capacity doing adaptation activity and behavior at household level and agriculture activity. Figures 9 and 10 show three major adaptation behaviors in the watershed areas: house maintenance, move to a safe place, and update to a warning, although they have poor literacy, awareness, and infrastructure. Figure 9 shows heterogeneity in household adaptation behaviors across three VDCs clusters of the study area where about 66.7 percent of households preferred house maintenance rather than about 33.3 percent of households move to a safe place in Gadhi. About 100 percent of the households of Lekhagaon and Kunathari had a single choice of update of warning and move to a safe place respectively.

Figure 10 depicts major adaptation behaviors in agriculture: house/land maintenance, wall construction, and residual removal, along with seed shifting and irrigation facility. In Gadhi, farmers employ equally these three adaptation options with 33.3 percent weightage. However, about 100 percent farmers use removing residuals options in Lekhagaon meanwhile all farmers prefer to construct a bamboo wall to control flood and landslides.

At an individual level, indigenous small farmers prefer to construct environmentally friendly cost-effective bamboo walls to protect the fertile land from soil erosion and flooding unwanted residuals (stone, leaf, iron, etc.) in the watershed areas. Besides, negligible farmers change indigenously crop, seed, and technology, along. Its result is positive to save more than 40 percent loss in wheat crop productivity and revenue income. Similarly, the local government allocates a budget to construct infrastructure to minimize natural risks in the watershed areas.

Figure 7: Household Adaptive Behavior during Climate Shock



Source: Field Survey, 2020

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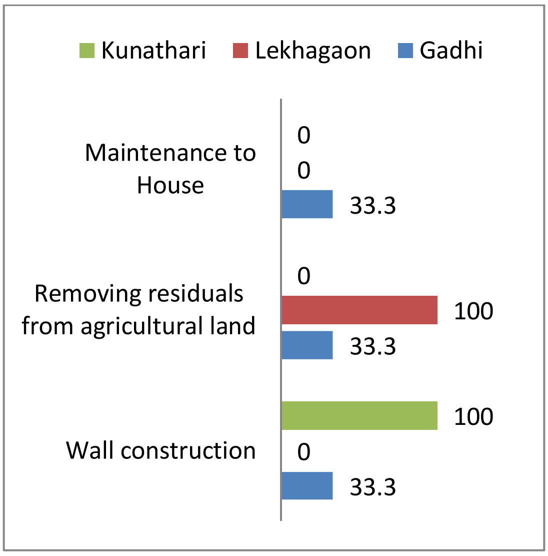
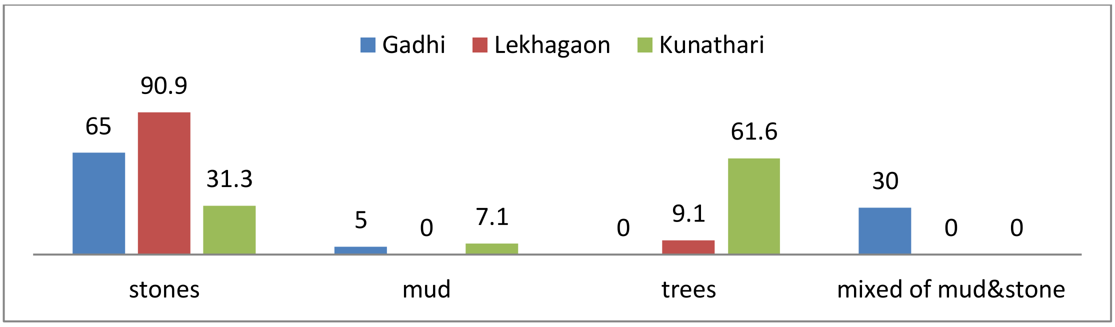
Figure 8: Household Adaptive Behavior in Agriculture



Source: Field Survey, 2020

Figure 9: Residual Composition (%)



Source: Field Survey, 2020

Figure 10 shows a heterogeneous component of residuals such as stone, mud, and tree deposited in the agricultural land. In Gadhi, stone (65%) dominates mud (5%) and tree (4.1%) in residuals deposited. In Lekhagaon, stone (90.9%) dominates the tree (9.1%). Similarly, in Kunathari, trees (61.6 %) dominate stone (31.3%) and mud (7.1%).

Descriptive Analysis

Table 1 presents the mean and standard deviation of key variables in multiple semi-log regression model estimation. In column 1, there are 10 variables in which household vulnerability in terms of income lost in log form (ln rice revenue) is dependent variable and labor (L), land (L_a), fertilizer (F), Seed(S), D_0(climate shock), D_1(adaptive shock), D_2 (Gadhi), D_3 (Lekhagaon) and D_4 (Kunathari) are independent variables. Standard deviations of these variables from the mean are not so significant. The mean of these variables represents properly household data collected from primary sources.

Farmers produce 0.27-ton wheat on average in 0.69 bighas (0.17 hectare) land size and generate 1350 Rs (13.5 USD). The model shows 5.14 ln wheat revenue, that is 170 Rs if all variables are constant. It would depend on a higher ratio of labor and seed but less fertilizer, although there is a higher prevalence of natural hazard risk (flood at 0.94 and landslides at 0.06). Farmers have the adaptive capacity and adaptation behavior (See in Table 1).

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Table 1: Mean and Standard Deviations: Semi Log Regression Model Estimation

Variables	Mean (Std. Deviation)
Revenue generated from wheat production (ln wheat reve)	5.14(4.14)
Land (ln area wheat)	0.69(1.08)
Labor (In no Labor)	1.21(1.00)
Seed (In seed)	1.35(1.05)
Fertilizer (ln Ferti)	0.41(1.25)
Occurrence of climate shock (1=Flood 0=others(landslides)	0.94(.22)
Adaptive Shock 1: Wall Construction (1=Yes, 0=others)	0.58(.49)
D_1(Gadhi)	0.13(.34)
D_2 (Lekhagaon)	0.22(.42)
D_3 (Kunathari)	0.63(.48)

F-value=2.47, Df=8, 118, At 5 percent, R^2=0.64

Empirical Results

Table 2 provides the results of the semi-log regression model of the dependent variable in log form (lnrice revenue) and 8 independent variables including labor (lnL), land (lnL_a), fertilizer (lnF), Seed (lnS) D_0 (climate shock), D_1 (climate adaptation), D2 (Gadhi), D_3 (Lekhagaon) and D_4 (Kunathari) are independent variables There are thirteen parameters: β, β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8, and β_9.

C-D Production Function

$$\ln Y_{wr} = 5.44 + 2.28 \ln L + 0.72 \ln L_{ag} - .67 - 1.29 \ln fl ns - 2.51 D_0(\text{climate shock}) + 0.13 D_1 (\text{adaptation shock}) + 1.58 D_2(\text{Gadhi}) - 0.43 D_3 (\text{lekhagaon}) + 0.43 D_4 (\text{kunathari})$$

Table 2: CD production function: Semi Log Regression Model Estimation

Regressor	1	2	3	4	5	6	7	8	9	10
Constant	5.44 (1.8)									
Proportion of labor in ag production (ln L)		2.28 (2.68)								
Proportion of land used in ag production (ln area of rice)			0.72 (.34)							
Proportion of fertilizer used in ag production(lnF)				-.067 (.44)						
Proportion of seed i agricultural production(lns)					-1.29 (2.55)					
Climate shock (yes=1, 0=others)						-2.51 (1.64)				

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D_1Adapt shock 1: wall construction (yes=1, others=0)							.13 (.757)			
D_2(Gadhi))(yes=1, 0=others)								1.58 (1.59)		
D_3 (Lekhagaon))(yes=1, 0=others)									-.43 (0.90)	
D_4 (Kunathari))(yes=1, 0=others)										.43 (0.90)

The above results of the semi-log econometric model provide sufficient and necessary evidence on the coefficient of independent variables on wheat revenue. Estimation of coefficient explains *how much the change of wheat revenue is affected by the change of adaptive capacity, geography, and climatic shock (the flood)*. In the result of the model, R^2 value is 0.64. It means the independent variables are exploratory at 64 percent. There is still a 35 percent error term which includes the different unobserved variables. It indicates higher goodness to fit.

Discussion

Wheat production is the main food crop in the agriculture sector of the Sot Khola sub-watershed area under the threat of climate change and climate change-induced hazards. Its negative consequences can be found in terms of production risk and instability. Wheat revenue has been fluctuation-induced household vulnerability. Therefore, a double log model of C-D production has been employed to understand the impact of a climate shock, adaptation behavior of households, and status and difference in areas (Gadhi, Lekhagaon, and Kunathari). In this way, the above independent variables have either positive or negative relationships with wheat revenue in those three VDCs: Gadhi, Lekhagaon, and Kunathari. Let us present one by one independent variable influencing wheat production.

- Despite inferior and unskilled labor, wheat production and revenue have a positive contribution to the labor unit. No labor employed in wheat production is significant to the wheat revenue to produce at a 1 % level. Assuming other variables are constant, but the labor input increases by 1 unit, the wheat production increases by 2.28 Rs of wheat revenue.

- The land is used for wheat production. If it is fertile, its contribution will be valuable in terms of productivity. If not, its contribution will be negative. In rural hilly areas, the land is found to have terraced land (less productive land and no access to irrigation). The area of land employed in wheat production is significant to the wheat revenue to produce at 1 % level. Assuming other variables are constant, but the land input increases by 1 Katha, the wheat production revenue increases by Rs. 0.72.

- Fertilizer is a major source of wheat crop nutrients. In wheat production, fertilizer is not used. After the preparation of land, wheat seeds are sown. It needs irrigation only. Therefore, wheat production completely depends on ecological, land, and seed input. Fertilizer in wheat production is significant to the wheat revenue to produce at 1 % level. Assuming other variables are constant, the fertilizer input increases by 1 Kg, the wheat production revenue decreases by Rs. 0.67.

- Seed is especially important to get higher productivity and production of wheat. Wheat seed is significant to the wheat revenue to produce at 1 % level. Assuming other variables are constant but wheat seed input increases by 1 unit, the wheat production revenue decreases by Rs. 1.29. Using present wheat seed in the production has a negative contribution on wheat productivity and production and then wheat revenue.

- Climate shock is captured in the Dummy variable (D_0) in which 1=flood and 0= landslides and others. Climate change-induced shock has affected fertile land through bank cutting, damage to crops, deposition of sedimentation in terrace land, destruction of irrigation system in the watershed areas. This dummy is significant to the wheat revenue. Let us assume other variables are constant. When there is the occurrence of flood, the wheat revenue will be Rs 2.93. In the case of landslides and others, the wheat revenue will be Rs. 5.44. Thus, both shocks have a difference of Rs. 2.51 in wheat production. Both harm wheat production and productivity.

- Farmers have used such knowledge as adaptation behavior and activity in terms of wall construction, seed change, and removing sedimentation. To capture such behavior and activity, the Dummy variable (D_1) is used 1 for wall construction and 0 for other (seed change and removing sedimentation). Let us assume other variables are constant but wall construction is constructed to prevent the flood, wheat revenue will increase by Rs.0.13 and then Rs 5.57. If not, wheat revenue will increase by 5.44 Rs. There is a difference between the two adaptation options, that is Rs. 0.13.

- $\ln Y_{wr}$= 5.44+2.28 lnL+0.72 $\ln L_{ag}$-.67 lnflns -1.29 lnseed -2.51D_0(climate shock) +0.13 D_1 (adaptation shock) +1.58D_2(Gadhi)-0.43 D_3 (lekhagaon)+0.43 D_4 (Kunathari)

- Ecological and altitudinal factors influence wheat production and productivity. In the watershed areas, there are three VDCs: Gadhi, Lekhagaon, and Kunathari. Assuming other variables are constant, the revenue from wheat production in the Lekhagaon is significantly lower than Gadhi and Kunathari at the 1 % level.

Thus, family members, landholding, knowledge, experience, and agricultural income influence household vulnerability. These variables have significant impacts.

Conclusion

This paper builds an analytical framework to estimate climate change and its vulnerability directly and indirectly on wheat production cycle and pattern and to estimate the effects of farmers' adaptation to minimize such vulnerabilities on wheat production and revenue using C-D production econometric models. Interesting empirical results are the occurrence of climate change and its vulnerabilities in household and agricultural activity by inducing disasters: floods and landslides. Despite poor, illiterate, and small farmers, their indigenous adaptation capacity prefers moving to safe places in households and low-cost environmentally friendly bamboo walls, removing residuals, and shifting seeds at wheat production. In wheat production, seed shifting and changing are effective in being resilient to climate change to minimize more than 40 percent revenue loss. The model's coefficient results in highly prevalent climate-induced disasters and effective indigenous adaptation capacity of small plots and farmers in wheat production. Therefore, indigenous adaptation skills and knowledge of small farmers should be upgraded along with the urgent building policy, program, and institution to be a climate-resilient agricultural activity for food security, livelihood, and welfare.

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Author's contribution

The author's contribution was to conduct the whole research project including data collection, analysis, methodological development, data analysis and write up the manuscript.

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Competing Interest

The author declares that he has no competing interest.

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