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# Determinants of Smallholder Farm Households' Adaptation Responses to Climate Change Induced Rice Insufficiency at Household Level in Sumedang District, Indonesia

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**Abstract**

The global concerns on climate change adaptation has now shifted from a high-level advocacy on "the need to adapt" to a regional or local level responses on "how to adapt".

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Keeping in mind the locally specific impact of climate change on agriculture and hence the smallholders' food insecurity, effective adaptation measures cannot be manifested, unless the stakeholders managed to master the locally specific context of the impacted system. This study provides an analysis on factors determining the diversity of the smallholder farm households' current adaptation responses to climate change induced household-level rice insufficiency, based on which recommendation could be formulated as to shifting individual household's existing adaptation response to the current best adaptation practice identified empirically in the study area. The result suggested that rice yield reduction impact of climate change affected the smallholder household's rice sufficiency level (HRSL) to the extent variable across different types of individual household's existing autonomous adaptation responses. Among the four general types of adaptations identified, the combined on- and off-farm adapted group generated the highest HRSL, followed consequently by the off-farm and on-farm adapted group. Under baseline, the average HRSL of the three types of adaptations are recorded at 61.64%, 58.40%, and 56.12%, respectively, higher than that of the non-adapted which is 54.53%. In terms of resilience to future climate, the result of the study indicated that the combined on- and off-farm adapted households have been the most resilient group, as indicated by its lowest HRSL reduction, both to the near and far-future projection. While the off-farm adapted generated higher HRSL, the on-farm adapted group indicated better resilience to changing climate than the off-farm adapted. Similar pattern in climate change-induced rice yield and its implication on HRSL was shared between RCP4.5 and RCP8.5 for both near- and far-future projections. The result of adaptation determinants analysis suggested that climate change adaptation-strengthening intervention to the study area should be better targetted to female-, older-age-, and lower-educated headed households. Moreover, the interventions should focus more on activities that expose these households to climate change-related innovation and technology on the one side, and improve the household's access to credit, and hence financial resources, on the other side, through which the smallholder households gain sufficient capacity to adopt the empirically identified existing best adaptation practice.

***Keywords:*** Climate Change; Rice Insufficiency; Adaptation; Determinant Analysis.

## 1. Introduction

While climate change is a global phenomenon, its impact on agriculture has been locally specific context. Climate change affects the agricultural sectors to the extent highly variable across different regions, depending on their vulnerability condition [1,2]. However, it is clear that smallholder farm households who rely greatly on agriculture for their survival are among the worst affected [3,4]. Failure to adapt will expose them to possibly more severe and long-term consequences, such as reduced food crop productivity that often lead to severe food insecurity. The smallholder seems to have no alternative but to adapt their livelihood systems to the changing climatic conditions. Therefore, there is an urgent need for the global community to focus its attention on identifying adaptation measures that can help these farmers reduce their vulnerability to climate change and cope with the adverse consequences.

The global concerns on climate change adaptation has now shifted from a high-level advocacy on "the need to adapt" to a regional or local level responses on "how to adapt" [5]. Keeping in mind the locally specific impact of climate change on agriculture and hence the smallholders' food insecurity, effective adaptation measures cannot be manifested, unless all stakeholders managed to master the locally specific context of the impacted system. In fact, several practical options for adaptation exist among the impacted community as part of their coping mechanism or autonomous adaptations to disturbances. However, owing to their limited resources and capacity, the current autonomous adaptation responses of smallholder have often been insufficient, and hence forced them to come in and out of undernourishment. In order to implement appropriate interventions, governments need to understand the opportunities for adaptation and the key drivers behind voluntary adaptation by vulnerable smallholder farmers.

Studies on climate change impact and adaptation have been growing, both at macro- and micro-level. The recent development of macro-level studies focus on simulation of the efficacy of sets of possible adaptation options in addressing the current and future impact of climate change, based on which set of prescriptive adaptation interventions were formulated to ensure food security at global, national, or regional level [6]. Meanwhile, at micro-level, recent adaptation studies have been focusing on testing whether or not a farm household has adopted a particular type of the prescriptive adaptations in addressing its perceived changes in climatic condition and the subsequent impact on household food insecurity. In addition, analysis of factors that determine a farm household adoption of a particular type of adaptation has also been a focus of the micro-level study [7,8].

Given the locally specific character of climate change impact and hence adaptation responses, there is no single set of adaptation intervention that fits all conditions of different locations. Understanding the overall local vulnerability has been recognized as a key to generate locally-rooted and hence successful adaptations [9,10]. It is therefore imperative to study the locally specific characteristics of a system under study, in terms of the extent to which it has been affected by the changing climate, the diversity in autonomous adaptation responses within the system, the efficacy of each of those autonomous responses, as well as factors that constraint a household from adopting the locally identified most effective adaptation measure.

This study provides an analysis on factors that underly the diversity of the smallholder farm households'current adaptation responses to climate change induced household-level rice insufficiency, based on which recommendation could be formulated as to shifting individual household's current adaptation response to the current best adaptation practice identified empirically in the study area. In specific, the study aims to (i) Identify the diversity of smallholder farm households' current adaptation responses, (ii) assess the extent to which each individual household's current adaptation response withstand the rice insufficiency impact of climate change, and (iii) investigate factors that explain a farm household's current adoption of a particular type of adaptation and how it deviates from the empirically identified best adaptation response.

## 2. Material and Method

### *2.1. Study Area*

The study was conducted in Ujungjaya Sub district, the District of Sumedang, West Java Province, Indonesia. The study area covered all the nine villages available in Ujungjaya Sub-district, namely Cibuluh, Cipelang, Keboncau, Kudangwangi, Palabuan, Palasari, Sakurjaya, Sukamulya, and Ujungjaya Villages. The location lies approximately between longitudes 107°84' - 108°82' E and latitude 6°84' - 7°84' S, with the altitude of 50 m above sea level, indicating the lowest area of Sumedang District (Figure 1). Ujungjaya Sub-district covers a landmass of 8,122 ha, where agriculture occupies 2,637 ha or around 32.47%. According to its water supply, farming is divided into rain-fed, whose water supply is exclusively derived from rainfall, occupying 828 ha or 31.40%; and the remaining 68.60% are irrigated, whose water supply is supplemented and/or regulated by irrigation infrastructure, which ranges from very simple to well-constructed canal. The main commodity planted by farmers is rice, with most popular variety is Ciherang whose growing period is around 120 days. The average annual productivity of rice in the district was recorded at 6.28 ton/ha [11].


**Figure 1:** Map of Study Area

In the study area, irrigation infrastructure mostly, if not all, has no sufficient capacity to maintain stable water supply for farming all year around. This is because irrigation infrastructure is not equipped with well-constructed water storage facilities to accumulate water from rainfall during rainy season and release it during the dry season. The average annual rainfall of the area is around 2,597 mm during the last 5 years, the lowest in comparison to that in other sub-districts of Sumedang.

Ujung Jaya Sub-district has average population growth of 0.17% and total households of around 9,726 [11], where around 37.44% fall into poor household category based on indicators developed by Social Protection Programs [12]. Majority of the people (72.68%) are farmers.

### *2.2. Sampling*

Sample households were calculated using the following formula:

$$n = \frac{Z^2_{1-\alpha/2}\, p(1-p)N}{d^2(N-1) + Z^2_{1-\alpha/2}\, p(1-p)} \quad (1)$$

Where:

n = Number of minimum sample required

α = Confidence interval (95%)

$\boldsymbol{Z_{1-\alpha/2} = 1,96}$

p = Proportion of climate change-induced food-insecure households (estimated based on the percentage of farm plots suffering from planting/harvesting failure to the total farm plots affected by drought, flood, and pest/diseases infestation. Using the Sumedang District Agricultural Office (ADO) data, the proportion was estimated at 0.32)

d = Limit error or absolute precision (0,05)

N = Total Population, i.e. all households in the study area whose welfare fall within the lowest fourth deciles, which according to the 2011 Data Collection for Social Protection Programs (PPLS) conducted by Statistics Indonesia (BPS), the total number was around 3.641 households [12].

Based the above formula, it is found out that the required number of sample for this study was 156 households. The sample was selected randomly from the "by-name and by-address" data of the 3.641 households, which has been released officially by PPLS.

### *2.3. Data Collection*

Data collection was conducted from November to December 2013. It was just after planting for some households and during planting or land preparation for some others. Data was collected using questionnaire through interview with the housewife together with the head of sample households. Interview was made at the house of sample households, upon a prior appointment for most convenient time to the respondents. Two couples of experienced interviewers were recruited and short training to familiarize the questionnaire was made prior to the data collection. In order to verify the data generated from the interview, a triangulation was made through Focus Group Discussion (FGD) and interview with key informants, field observation, and secondary data collected from related local offices.

Data collected included: (i) household's rice production system that involved current farm management practices, current yield, and current allocation of its production; (ii) household's consumption pattern assessed by weekly-based household food consumption through interview with the housewife to generate data on the portion of total household calorie requirement derived from rice; and (iii) household's socio-economic, demographic, and environmental characteristics to explore factors determining the household's choice of a particular adaptation practice. In addition, observed climate data of precipitation and minimum and maximum temperature was also collected for 30 years (1981 – 2010) from local climate station located closest to the study area, which is Jatiwangi Climate Station. Based on which, the projected changes in average monthly rainfall and minimum and maximum temperature was generated for two time slices, i.e. near-future (2011 – 2040) and far-future (2041 – 2070). The 30 years period was chosen considering that this is the minimum period needed to define a climate.

### *2.4. Data Analysis*

#### *2.4.1 Calculation of HRSL under Changing Climate*

The study applied 17 General Circulation Models (GCMs) under climate change scenarios of RCP8.5 and RCP4.5 to generate simulated climate (precipitation and minimum and maximum temperature) for baseline, near-future and far-future periods, specifically for the study area. The GCMs used include BCC-CSM1, CCSM4, CESMI-CAM5, CSIRO-Mk3-6-0, FIO-ESM, NOAA GFDLCM3, NOAA GFDL ESM2G/2M, GISS-E2-R1-3, HadGEM2-ES, IPSL-CM5A-LR, MIROC5, MIROC-ESM, MIROC-ESM-CHEM, MRI-CGCM3.

The outputs of the GCMs were then used as input for CROPWAT model [13,14] to generate estimates of climate change-induced rice yield reduction. Prior to its application, the CROPWAT was adjusted by local data to represent the local farming condition. The adjustments made include planting time, irrigation scheduling, and crop and soil characteristic. The irrigation schedule option of CROPWAT was set for "rain-fed" and "irrigate at fixed interval per stage". Based on data collected through interview with local farmers and field observation, the interval of irrigation for different stages of rice development was defined according to different planting times at fixed application depth of 20 mm. Adjustment was also made for crop and soil data to match the local specific condition of the study area.

Based on the output of CROPWAT model, the average annual rice yield for individual sample household was calculated for baseline, near-future and far-future. The average annual rice yields then enter into equation 2 to generate individual HRSL for the three periods. A comparison was then made among those periods for both adapted and non-adapted households to assess the adequacy of the current adaptation practices.

$$HRR = p \; x \; 2400 \; x \; c \; x \; h \; x \; 365 \quad \textit{(Kg Rice/Household/Year)} \qquad (2)$$

*Where:*

*p = Portion of the total household calorie requirement derived from rice (assessed by weekly-based household food consumption through interview with housewife)*

*c = Calorie-to-rice conversion factor, where 100 gram rice contained 360 kcal* [15]

*h = Number of household members*

In addition, the annual actual availability of rice at household level (HRA) was also assessed using the following formula:

$$HRA = \sum_{i=1}^{n}(y_i \; x \; l_i) - (c + s) + np \quad \textit{(Kg Rice/Household/Year)} \qquad (3)$$

*Where:*

*y = Harvesting Yield (as reported by head of sample household during interview) x Conversion Factor* *from Harvesting Yield to Ready-to-Husk Grain (86.02%) x Conversion Factor from Ready-to-Husk Grain to Rice (62.74%)*

*l* = *Harvesting area (ha)*

*n* = *Times of planting (n=2 for rain-fed farm plots and n=3 for irrigated farm-plots)*

*c* = *Portion of harvest allocated to cover cost of production (wage, seed, rent, etc.)*

*s* = *Portion of harvest sold for purposes other than cost of production*

*np* = *Food from sources other than households' own farm production (external sources)*

The HRSL was calculated individually for each sample household using individual household data generated from the household survey.

### *2.4.2 Analysis of Determinants of Farm Households' Current Adaptation*

The ordinal logistic regression analysis was employed to analyze factors determining the shifting of a farm household from one particular type of adaptation to another. In this case, types of adaptations, as response variables, assumed an ordinal scale covering "non-adapted", "either on- or off-farm adapted" and the "combined on- and off-farm adapted". The ordinal logit model is as follows:

$$Y_j^* = X_j^I \beta + U_{Ij} \quad (4)$$

Where Y is the choices of adaptations that involved ordered response variables, that is, Y=0 to indicate a household's choice to be "non adapted"; Y=1 to represent a household's choice to be "either on- or off-farm adapted"; and Y=2 indicating household's choice to be the "combined on- and off-farm adapted". The $X_{ij}$ are the explanatory (independent) variables determining a household's choice of a particular adaptation. The independent variables included in the model were gender, education, and age of household head; household size; farm size; livestock ownership; involvement in farmer group; access to credit; percentage of a household's rice requirement derived from its own farm production; the existence of irrigation channel; the length of a household's facing food scarcity; and distance of household's farm plot to irrigation water reservoir. The $\beta\beta_s$ are parameters estimated and $U_{ij}$ is the disturbance term. $Y^*$ is unobserved, but what was observed in this study is $Y = 0$ if $Y^* \leq \mu1$; $Y = 1$ if $\mu1 < Y^* \leq \mu2$; and $Y = 2$ if $Y^* > \mu2$.

The interpretation of the above ordinal logistic regression output was carried out in terms of change in predicted probability for discrete change in the ordinal response variables. For example, the discrete changes in the predicted probability of a certain outcome for a change in $X_i$ from baseline say, $X_0$, to the final value say to, $X_c$:

$$\frac{\Delta Prob(y=t/X)}{\Delta X_i} = prob(y = t/X, X_i = X_c) - prob(y = t/X, X_i = X_0) \quad (5)$$

Where Prob(y=t|X, $X_i$) is the probability that y=t given X, by assigning specific value to $X_i$. The change in the probability is interpreted as indicating that when $X_i$ changes from reference level, in this case the largest numeric value ($X_{c)}$ to $X_0$, the predicted probability of outcome t, holding other variables constant, changes by:

$$\frac{\Delta Prob(y=t/X)}{\Delta X_i} \qquad (6)$$

## 3. Results and Discussion

### *3.1. The Diversity of Smallholder Households' Current Climate Change Adaptations*

The study categorized the large number of smallholder households' adaptation responses to food insecurity implication of climate change, to range from "non-adapted", on the one extreme, to the "combined on- and off-farm adapted", on the other. Between the two extremes are those who are being "either on- or off-farm adapted". Afterward, the study contextualized those categories of adaptations into the local condition of the study area. The off-farm adaptations represented whether or not a smallholder household has diversified its livelihood to off-farm employment(s), which most likely generate cash income, and hence influence the household's access to external sources of rice, to the extent highly variable among the smallholders. In the context of the study area, the readily available source of rice at an affordable price for the poor is the government-subsidized rice known as *Raskin*. Though the smallholders are only charged Rp1.600.00/kg *Raskin* (much cheaper than the market price of regular rice with similar quality, which at the time of data collection was around Rp6.400.00), only small portion of the poor smallholders gain full benefit from the total 15 kg *Raskin* allocated for each poor households per month. While, major portion of poor households in the study area only afford on average 5 kg *Raskin* per month, some households managed to buy on average 10-15 kg *Raskin* per month. The households are mostly those who have been off-farm adapted.

Meanwhile, on-farm adaptation responses represented the diversity of the smallholder households' current farming practices identified in the study area, as described on Table 1. The Current farming practices of smallholder households in the study area are diversified mostly by planting time and irrigation scheduling, as well as to a little extent by methods of land preparation and rice varieties planted.

According to its water supply, farming in the study area is divided into rain-fed, where water supply is exclusively derived from rainfall, and irrigated whose water supply is supplemented and/or regulated by irrigation infrastructure. In the study area, however irrigation infrastructure mostly, if not all, has no sufficient capacity to maintain stable water supply for farming all year around. This is because irrigation infrastructure is not equipped with well-constructed water storage facilities to accumulate water from rainfall during rainy season and release it during the dry season.

Planting time generally follows the pattern of rainfall. In the rain-fed areas, planting is generally made at most 2 times a year, where the first links to the onset of rainy season (usually in October, November, December, or January), while the second starts immediately after the first harvesting. The second planting time is highly critical in relation to the pattern of rainfall, where the risk of failure resulting from limited water supply is critically high. Farmers are fully aware of the risks but for most of them little they can do due to their limited resources. They just rely on their fortune, hoping that enough rain will still occur until harvesting. Meanwhile, in irrigated areas, planting time is relatively more flexible, made possible by supplementary water supply from irrigation. Planting in irrigated farm occurs at almost every month, though the general pattern still follows that of the rainfall. Most of rice farm areas are cultivated under the third type of current farming practices, where around 88.89% and 95.41% of the first and second planting belong to the planting time of December and April, respectively (see Table 1).

**Table 1:** Description of Current farming practices of smallholders in the study area

| Current Farming Practices | Planting Time | Irrigation Scheduling[1)] | Land Preparation | Rice Variety | Planting Area (Ha) |
|---|---|---|---|---|---|
| **Irrigated:** | | | | | |
| Farming I1 | October | 3-3-7-7 | Tillage | Ciherang | 103 |
| (On-I1) | February | 7-10-14-14 | | | 40 |
| | June | 7-14-14-14 | | | 20 |
| Farming I2 | November | 3-3-7-7 | Tillage | Ciherang | 157 |
| (On-I2) | March | 7-10-14-14 | | | 51 |
| | July | 7-14-14-14 | | | 42 |
| Farming I3 | December | 3-3-7-7 | Tillage | Ciherang | 2.281 |
| (On-I3) | April | 7-10-14-14 | | | 2.100 |
| | August | 7-14-14-14 | | | 22 |
| Farming I4 | January | 3-3-7-7 | Tillage | Ciherang | 25 |
| (On-I4) | May | 7-10-14-14 | | | 10 |
| | September | 7-14-14-14 | | | 30 |
| **Rain-fed:** | | | | | |
| Farming R1 | November | No Irrigation | Tillage | IR64 | 455 |
| (On-R1) | February | | No Tillage | | 11 |
| Farming R2 | December | No Irrigation | No Tillage | IR64 | 84 |
| (On-R2) | March | | | | 13 |
| Farming R3 | January | No Irrigation | No Tillage | IR64 | 15 |
| (On-R3) | April | | | | 65 |

Note: [1)] Irrigation interval for 4 critical stages of rice growth (20-45-65-120 days After Planting)

Irrigation scheduling is determined to the greatest extent by access to irrigation water reservoir. The flow of irrigation water to farm plot is generally regulated on a rotational-based, with an average application interval of 3 days during the earlier stages of rice growth and 7 days during the later stages. However, when water is not adequately available (usually during dry season), the application interval was prolonged until 7 or 10 days during the earlier stages and often until 14 days during the later stages. The depth of water irrigation in each application is set relatively constant, generally at a level of no more than 20 mm. The frequency of irrigation application varies for different locations of farm plots, depending on their access to water reservoir. For those farmers whose farm plot has limited access to water reservoir (e.g. rain-fed or farm plots with irrigation canals but located far-off the reservoir), irrigation supply is most likely getting scarce for the second or third planting time. In this condition, supplementing irrigation with water pumps could be an alternative solution. But, this is only possible for famers who own adequate resources, while those who cannot afford the pumps just rely exclusively on rainfall.

The main varieties of rice commonly grown by the local farmers are Ciherang and IR64. There are also other rice varieties grown, but still very limited, i.e. Mekongga, Inpari 4, and Inpari 10. Among the very limited farmers who grow varieties other than Ciherang mentioned that they grew the variety simply as a trial and they treat it relatively equal to Ciherang. According to the local farmers, the average growing period of those varieties is relatively similar, that is around 120 days, from planting to harvesting.

According to the local practices, planting rice generally starts with land preparation and raising the seedlings in a nursery, prior to the transplanting of seedling in the main field. Small numbers of farmers do direct planting, where seeds are drilled directly to zero tilled land, but this practice is only limited to dry-season planting of the rain-fed farm. The main motivations of farmers to do zero-tilled direct planting are to save water and at the same time shorten the growing period, so that they can gain early harvest, giving them more flexibility for the next planting.

Step of farming, which requires large amount of water, is land preparation. For those farmers whose farm plots are close to irrigation reservoir or those who own enough resources to make better access to water supply, land preparation can be done immediately at the onset of rainy season. Meanwhile, farmers with limited resources or those whose farm plots are far off the reservoir should wait until the level of reservoir high enough to flow, or until water from rainfall is sufficiently accumulated in their farm plots. This subsequently results in the variety of smallholders' planting calendar and irrigation scheduling.

### *3.2. Smallholder Households' Rice Sufficiency Level and Current Adaptations under Climate Change*

The result of climate change analysis, as presented on Table 2, confirmed that climate change has been occurring in the study area. The average of the 17 GCM-simulated climate under climate change scenario of RCP4.5 indicated that average annual rainfall has been decreasing by 6.81% and 7.34% for near- and far-future period, respectively. Meanwhile, the minimum and maximum temperature were projected to increase by 0.65$^{o}$C and 0.69$^{o}$C for near-future period, and then further increased by 1.23$^{o}$C and 1.28$^{o}$C for far-future period. Similar projected changes in climatic condition were indicated to slightly higher extent under climate change scenario of RCP8.5 for near- and far-future periods.

Climate change affected smallholder household's rice sufficiency level (RSL) through its impact on the yield of household's farm plot. Under this study, the implication of changing climate on rice yield was simulated for irrigated and rain-fed farming by using a crop simulation model of CROPWAT 8.0 under the various current farming practices, as defined above (see Table 1). The result, as presented on Table 3, suggested that the diversity in current farming practices has resulted in different level of rice yield both under irrigated and rain-fed farming. The result also indicated a decrease in rice yield to occur for near- and far-future periods to the extent variable across different farming practices. The highest rice yield was generated by the farming practice of On-I3 for irrigated farming and by On-R1 for the rain-fed, where under baseline period, the yield was recorded at 56.62 quintal/hectare and 41.30 quintal/hectare, respectively. Both farming practices, at the same time, also generated the most stable rice yield to the near- and far-future projection, as indicated by their lowest yield reduction, relative to that of the other farming practices (see figure in parenthesis on Table 3). Similar pattern in climate change-induced rice yield was shared between RCP4.5 and RCP8.5 for both irrigated and rain-fed farming. The analysis of rice-yield reduction impact of climate change for different current farming practices has been discussed in more detail in [16].

**Table 2:** Projected changes of climatic condition in the study area (average of 17 GCMs)

| Climate Components | RCP4.5 | | | RCP8.5 | | |
|---|---|---|---|---|---|---|
| | **Baseline** | **Near-future** | **Far-future** | **Baseline** | **Near-future** | **Far-future** |
| Rainfall (mm) | 1,302.89 | 1,237.66<br>(-5.01) | 1,222.00<br>(-6.21) | 1,317.32 | 1,227.64<br>(-6.81) | 1,220.63<br>(-7.34) |
| Min Temp ($^{o}$C) | 25.34 | 25.99<br>(0.65) | 26.57<br>(1.23) | 25.34 | 26.09<br>(0.75) | 27.12<br>(1.78) |
| Max Temp ($^{o}$C) | 28.67 | 29.36<br>(0.69) | 29.95<br>(1.28) | 28.68 | 29.51<br>(0.83) | 30.58<br>(1.90) |

Note: Figure in parentheses indicated percent of change from baseline (%)

Taking the above findings into consideration, the study defined four adaptation categories to represent the local farm households' current responses to both the actual and potential impact of climate change on their household rice sufficiency level. These involved non-adapted, on-farm adapted, off-farm adapted, and the combined on- and off-farm adapted categories. The on-farm adapted group involved farm households whose current farming practices generated highest rice yield, or according to Table 3, those currently assuming the On-I3 farming practice. In addition, those households generally also worked on on-farm employment, typically being farm labor for land preparation, weeding, and harvesting. Meanwhile, the off-farm adapted group included those whose current farming practices fall within categories other than the On-I3. The households typically diversified their livelihoods to off-farm employments, which generate more cash income and hence better access to external sources of rice (in particular, the government subsidized rice for the poor/*Raskin* program). The off-farm adapted group is characterized by greater access to *Raskin* than the non- and on-farm adapted group. The Combined on- and off- farm adapted group covered those households who made both on- and off adaptations, while the non-adapted group covered those who made neither on- nor off-farm adaptation.

In order to gain an insight into the extent to which the smallholders' current adaptation practices withstand the food insecurity-impact of climate change, the Household Rice Sufficiency Level (HRSL) of 156 sample households was calculated individually based on individual household data generated from household survey. Based on which, afterward, the average HRSL of those fell within each of the four types of adaptations was calculated. The result, as presented on Table 4, suggested that though the adapted groups showed higher average HRSL than the non adapted, both still fell within the category of rice-severely insufficient as indicated by their average HRSL, which is still less than 70%. Moreover, the result indicated that the combined on- and off-farm adapted group generated the highest HRSL, followed consequently by the off-farm and on-farm adapted group. Under baseline, the average HRSL of the three types of adaptations are recorded at 61.64%, 58.40%, and 56.12%, respectively, higher than that of the non-adapted which is 54.53%.

**Table 3:** Climate change-induced rice yield reduction under current farming practices

| Current Farming Practices | Rice Yield (quintal/hectare) | | | | | |
|---|---|---|---|---|---|---|
| | RCP4.5 | | | RCP8.5 | | |
| | Baseline | Near-future | Far-future | Baseline | Near-future | Far-future |
| **Irrigated:** | **54.42** | **51.92** | **51.44** | **54.19** | **51.78** | **51.22** |
| On- I1 | 51.70 | 49.55<br>(-4.16) | 49.17<br>(-4.89) | 51.68 | 49.41<br>(-4.39) | 48.96<br>(-5.28) |
| On- I2 | 54.50 | 52.13<br>(-4.34) | 51.66<br>(-5.22) | 54.43 | 52.02<br>(-4.44) | 51.38<br>(-5.61) |
| On- I3 | 56.62 | 54.36<br>(-3.99) | 53.90<br>(-4.80) | 56.29 | 53.96<br>(-4.13) | 53.45<br>(-5.03) |
| On- I4 | 52.77 | 50.05<br>(-5.15) | 49.46<br>(-6.28) | 52.41 | 49.82<br>(-4.95) | 49.20<br>(-6.13) |
| **Rain-fed:** | **38.56** | **37.69** | **37.47** | **38.56** | **37.73** | **37.62** |
| On- R1 | 41.30 | 40.85<br>(-1.08) | 40.80<br>(-1.20) | 40.33 | 39.87<br>(-1.12) | 38.83<br>(-1.23) |
| On- R2 | 40.86 | 40.43<br>(-1.07) | 40.34<br>(-1.28) | 39.90 | 38.48<br>(-1.03) | 37.41<br>(-1.19) |
| On- R3 | 34.14 | 32.44<br>(-4.98) | 31.97<br>(-.6.36) | 33.07 | 31.47<br>(-4.70) | 30.25<br>(-5.34) |

Note: Figure in parentheses indicated percent of change from baseline (%)

Better HRSL of the off-farm adapted group, in comparison to that of the on-farm adapted, linked to fact that off-farm adaptation provided additional cash income to farm household, which resulted in increased household's economic access to external sources of rice. When it is combined with improved physical access to rice, made possible by government subsidized rice program (*Raskin*), off-farm adaptation tend to be more effective to bring the HRSL to a higher level. In terms of resilience to future climate, the result of the study indicated that the combined on- and off-farm adapted households have been the most resilient group, as indicated by its lowest HRSL reduction (see the figure in the parentheses of Table 4) both to the near and far-future projection. Moreover, the on-farm adapted group indicated better resilience to changing climate than the off-farm adapted. This could be justified by the effective role of the on-farm adaptation in reducing the climate change-induced reduction of rice yield, which in turn lessened the rice insufficiency implication of climate change. This finding is supported by previous study, which suggested that on-farm adapted households produced consistently more food than the non-adapted, due to a decreased risk of crop failure [17,18].

**Table 4:** Households' rice sufficiency level (RSL) and current adaptations under changing climate

| **Current Adaptation** | **No of Sample (N=156)** | **Household Rice Sufficiency Level (%)** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **RCP4.5** | | | **RCP8.5** | | |
| | | **Baseline** | **Near-future** | **Far-future** | **Baseline** | **Near-future** | **Far-future** |
| Non-Adapted | 71 | 54.53 | 52.21<br>(-4.25) | 50.74<br>(-6.95) | 54.38 | 52.05<br>(-4.28) | 50.52<br>(-7.10) |
| On-farm | 20 | 56.12 | 54.34<br>(-3.17) | 53.93<br>(-3.90) | 55.83 | 54.25<br>(-2.83) | 53.80<br>(-3.64) |
| Off-farm | 22 | 58.40 | 54.87<br>(-6.04) | 52.68<br>(-9.79) | 58.04 | 54.17<br>(-6.67) | 52.54<br>(-11.20) |
| On-&Off-farm | 43 | 61.64 | 60.85<br>(-1.28) | 60.28<br>(-2.21) | 61.29 | 60.59<br>(-1.14) | 59.80<br>(-2.43) |

Note: Figure in parentheses indicated percent of HRSL reduction from baseline to the near- and far-future period (%)

Overall, the result of the study indicated that the farm households' current adaptation practices have yet to be adequate to bring about household-level rice sufficiency for the smallholders, which suggested the need for improving the farm households' current adaptation measures. Substantial number of previous studies suggested that formulation of intervention to strengthen the smallholders' current adaptations to climate change required better understanding on factors that shape the smallholders' decision to adopt a particular type of adaptation

[7,19,20,21]. Moreover, the results also suggested that among the four types of farm household's current adaptations, the combined on- and off-farm adaptation ranked the highest efficacy in generating the highest, and at the same time the most stable, HRSL for farm households in the study area. However, there is no sufficient evident to claim which is the better between the on-farm and the off-farm adaptations, since the on-farm is the better in terms of maintaining stable HRSL under future changing climate, but less effective in generating higher HRSL. It is therefore, for further analysis, the four types of current adaptations are re-categorized into three categories, where the "combined on- and off-farm adaptation" rank the highest, and followed consequently by the "either on- or off-farm adaptation" and the "non-adaptation". Along this argument, further analysis was made to elaborate factors that explain a household's not adopting the empirically identified current best adaptation practice, in this case the combined on- and off-farm adaptation

### *3.3. Factors Underlying Smallholder Households' Current Adaptation Practices*

Socioeconomic, demographic and environmental factors have been demonstrated in substantial numbers of previous studies to influence farm households' adaptation strategies to food insecurity impact of climate change [8,22]. It is therefore, in order to gain thorough understanding on factors underlying the smallholders' current adaptations in the study area, twelve socio-economic and demographic factors assumed to influence the smallholder's current adaptation practices were tested using both descriptive (frequency and percentage distribution) and inferential (Chi-square, ANOVA, and Multinomial Logistic Regression) statistics. The summary of descriptive statistics, as presented on Table 5, indicated that the twelve factors tested, individually has significant link to smallholders' current adaptation, as indicated by the Chi-square- and ANOVA-calculated value that exceed the $X^2$ and F critical value at confidence interval of 99%. Those farm households whose head is male, having higher education, younger, or involved in farm group activities, are more likely to adapt to climate change than those whose characteristics are otherwise. These characteristics are often used by previous studies 23,24] to represent household's better access to innovation and technology, and when combined with households' better command over resources, as represented in this case by better access to credit, ownership of livestock, larger farm size, or larger household members, are most likely to bring about better capacity to farm household to adopt a better type of adaptation to climate change. This finding is consistent with that of previous study, which suggested that a household with improved access to extension services, and hence innovation and technology, in combination with improved access to credit, is more likely to adapt to changing climate [25,26].

Other characteristics that influence farm household's adaptation are distance of household's farm plot to water reservoir and the availability of irrigation canal connecting a household's farm plot to the reservoir.

The result suggested that the longer the distance of reservoir or the absence of irrigation canal, the more likely a household to adapt to climate change. The two factors represented the exposure of a household to the food insecurity implication of climate change. The remaining two characteristics tested are household's percentage of rice requirement derived from its own farm production and the length of household's facing food scarcity.

These factors represented the level of sensitivity of households to food insecurity impact of climate change. The result indicated that the higher the percentage of external supplied-rice or the longer the rice scarcity period, the more likely the household to adapt to climate change. In this case, higher exposure, and likewise higher sensitivity are considered as trigger for a household to adapt to the changing climate [27,28]. The more detailed analysis on the link between the exposure and sensitivity level to the current adaptation practices of farm households in the study area has been discussed in [29].

**Table 5:** Summary of descriptive statistics of adaptation determinants

| Scoring of Adaptation Determinants | | N | Non Adapted | On-or Adapted | Off-Farm | On-&Off-farm Adapted | |
|---|---|---|---|---|---|---|---|
| | | | **Percent of Sample (%)** | | | | **$X^2$ Values** |
| Gender of household head | | | | | | | 34.528* |
| - | Female (0) | 58 | 75.86 | 13.79 | | 10.34 | |
| - | Male (1) | 98 | 27.55 | 34.69 | | 37.76 | |
| Livestock Ownership | | | | | | | 6.811* |
| - | Not owned (0) | 75 | 54.67 | 26.67 | | 18.67 | |
| - | Owned (1) | 81 | 37.04 | 27.16 | | 35.80 | |
| Involvement in group | | | | | | | 53.826* |
| - | Not involved (0) | 69 | 76.81 | 18.84 | | 4.35 | |
| - | Involved (1) | 87 | 20.69 | 33.33 | | 45.98 | |
| Access to credit | | | | | | | 64.051* |
| - | No access (0) | 74 | 75.68 | 22.97 | | 1.35 | |
| - | Having access (1) | 82 | 18.29 | 30.49 | | 51.22 | |
| Irrigation | | | | | | | 43.569* |
| - | No canal (0) | 39 | 0.00 | 51.28 | | 48.72 | |
| - | With canal (1) | 117 | 60.68 | 18.80 | | 20.51 | |
| | | | **(Mean ± SD)** | | | | **$F_{Value}$** |
| HH head education | | | 7.10±1.45 | 9.71±2.18 | | 11.53±2.00 | 82.89* |
| HH head age | | | 47.41±6.43 | 39.95±3.87 | | 29.74±3.65 | 157.303* |
| HH size | | | 3.20±0.40 | 4.45±1.15 | | 4.11±1.27 | 76.804* |
| HH farm size | | | 0.05±0.01 | 0.06±0.01 | | 0.07±0.01 | 145.137* |
| %Rice from own farm | | | 58.45±8.89 | 67.40±0.12 | | 74.39±5.22 | 42.423* |
| Length of food scarcity | | | 3.37±0.72 | 3.59±0.89 | | 4.28±0.88 | 20.953* |
| Distance to reservoir | | | 0.48±0.10 | 0.70±0.15 | | 0.99±0.23 | 139.186* |

*) Significant at confidence interval of 99%.

Afterward, since the Chi-square and ANOVA statistics ($X^2$- and F-value) tested only partial link of individual factor to household's current adaptation practice, the multinomial logistic regression was then applied to test the interaction among the above twelve factors and their cumulative influence in shaping a farm household's decision to be either "non-adapted" or "either on- or off-farm adapted", instead of adopting the empirically identified current best adaptation practice, in this case the "combined on- and off-farm adaptation". Since it is considered that the response variables (the three identified adaptation types) assume a natural ordering, the study therefore, used the ordinal logistic regression module of the Minitab version 16 to perform the multinomial logistic regression. In this analysis, the "combined on- and off-farm adapted" group is set as reference category for the ordered logistic regression, and then given a highest score of 2. Meanwhile, the "either on- or off-farm adapted" and the "non-adapted" are being the second highest and the lowest, and then given a score of (1) and (0), respectively.

The result, as presented on Table 6, indicated that among the 12 factors tested, only six factors showed significant influence to households' adoption of a particular type of adaptation measure. The factors involved gender, age and education of household head; and household's access to credit, size of farm plot, and distance of the farm plot to water irrigation reservoir. In this case, the result implied that, at confidence interval of 90-95%, there is sufficient evidence to conclude that the six factors have been the main determinants for a particular household's decision on whether or not to adopt the empirically identified current best adaptation practice observed in the study area, i.e. the combined on- and off-farm adaptations.

The p-value for the Pearson and the Deviance test is 1.000, indicating that there is insufficient evidence to claim that the model does not fit the data adequately, or suggesting to accept the the null hypothesis that the model fits the data adequately. Moreover, the measure of association indicated that 99.6% of pairs are concordant, suggesting strong association between the observed responses and the predicted probabilities. In addition, Somers' D, Goodman-Kruskal Gamma, and Kendall's Tau-a are all closed to 1, suggesting a better predictive ability of the model. The statistic G of -14.682 with p-value of 0.000, suggested that there is sufficient evidence to conclude that at least one of the estimated coefficient is different from zero.

**Table 6:** Logistic estimates of the determinants of household's current adaptation

| ***Predictor*** | ***Coefficient*** | ***P*** | ***Odds Ratio*** |
|---|---|---|---|
| Constant (1) | 17.1523 | 0.029* | |
| Constant (2) | 33.0897 | 0.001** | |
| Gender of household head (1) | -4.49386 | 0.010* | 0.01 |
| Education of household head | -1.38089 | 0.007** | 0.25 |
| Age of household head | 0.385095 | 0.004** | 1.47 |
| Household Size | -0.687459 | 0.242 | 0.50 |
| Farm Size | -143.825 | 0.041* | 0.00 |
| Livestock ownership (1) | 0.280714 | 0.834 | 1.32 |
| Involvement in farmer group (1) | -1.22715 | 0.415 | 0.29 |
| Access to credit (1) | -3.74510 | 0.020* | 0.02 |
| Percent of rice from own farm production | 0.0075255 | 0.897 | 1.01 |

| | | | |
|---|---|---|---|
| Irrigation (1) | 1.56457 | 0.387 | 4.78 |
| Length of food scarcity | -0.587823 | 0.460 | 0.56 |
| Distance of farm plot to rater reservoir | -11.7307 | 0.010* | 0.00 |

Goodness-of-Fit Tests:

| Method | Chi-Square | DF | P |
|---|---|---|---|
| Pearson | 199.888 | 298 | 1.000 |
| Deviance | 29.364 | 298 | 1.000 |

Base category: "Combined on- and off-farm adapted"

Measures of Association:
(Between the Response Variable and Predicted Probabilities)

| Pairs | Number | Percent | **Summary Measures** | |
|---|---|---|---|---|
| Concordant | 7808 | 99.6 | Somers' D | 0.99 |
| Discordant | 28 | 0.4 | Goodman-Kruskal Gamma | 0.99 |
| Ties | 5 | 0.1 | Kendall's Tau-a | 0.64 |
| Total | 7841 | 100.0 | | |

Log-Likelihood = -14.682, G = 303.463, DF=12, P-Value=0.000

The values labeled Constant (1) and Constant (2) on Table 6 are estimated intercepts for the logits of the cumulative probabilities of the "either on- or off-farm adapted" and the "non-adapted", respectively. Because the cumulative probability for the last response ("both on- and off-farm adapted") have a value of 1, there is not need to estimate its intercept. The constants of 17.1523 and 33.0897 are equal to logit cummulative probabilistic closed to 100%, indicating that at its independent variables' score are all equal to "0", a household is most likely to be either "non-adapted" or "either on- or off-farm adapted", rather than being the "combined on- and off-farm adapted".

The negative coefficient, and the odds ratio that is less than 1 for the gender and education of household head, indicated that a female- and lower educated headed household tend to be associated with the household's not adopting the empirically identified current best adaptation practice, or the combined "on- and off-farm adaptation". Likewise, the negative coefficient, and the odds ratio that is less than 1 for household's farm size, access to credit, and distance of farm plot to water reservoir, suggested that a household's no access to credit, smaller size of farm plot, and shorter distance to reservoir tend to be associated with a household's not adopting the "combined on- and off-farm adaptation". Moreover, the possitive coefficient, and the odds that is greater than 1, indicated that older-age headed households tend to be associated with the household's not adopting the most effective adaptation practice, identified empirically in the study area.

In terms of the odds ratio, however, among the six factors, most has generated odds ratios closed to zero, suggesting that their influence to household's decision on whether or not to adopt the empirically identified current best adaptation practice, are considered to be minimal. In this case, only the education and age of household head showed a sufficient degree of influence, where a one-year reduction in household head's length of education, keeping in mind the "combined on- and off-farm adapted" as the refference category, bring about

25% increase in the odds of a household's not adopting the "combined on- and off-farm adaptations", given that all of the other variables in the model are held constant. Similarly, one-year older in the age of household head leads to 47% increase in the odds of a household's not adopting the "combined on- and off-farm adaptations", given that all of the other variables in the model are held constant.

Previous studies often linked the education of household head to household's access to innovation and technology, where the higher educated assumed the better adoption of innovation and technology. Meanwhile, the age of household head was often selected to represent a household's experience in farming, where the older age assumed to have better farming experience than the younger. The two factors, in combination, datermined a household access to a large range of adaptation options, and where further combined with households' better command over reources, improved the likelihood of a household to manifest the available adaptation options, which often require expensive investment, into his adaptation practices. Under this study, however, as already elaborated above, the link of the age of household head to household's adaptation showed otherwise, where the younger age had higher likelihood to adapt than the older. This could be justified by the local impact of the current superficially fast-growing globalization to the area, which support an argument that younger generation are typically more exposed to various sources of information and being more open-minded to innovation than the older generation. Moreover, the results of this study are consistent with previous studies' findings in that a household's better access to credit and larger farm size are more likely to be better adapted to the impact of changing climate, though the influence of the two variables is considered to be minimal, not more that 2%. Furthermore, the result of the study indicated that, though the influence is considered to be minimal, longer distance of household's farm plot to water reservoir has been associated with a household's adoption of better adaption to climate change. This suggested a need for efforts to bring simple water harvesting facilities closer to the household's farm plot.

Overall, the ordered logistic regression generated result consistant with that of previous studies, which suggested that the smallholder households' limited access to information and knowledge, and hence innovation and technology, in combination with limited access to resources, have been the main barriers for smallholders to adopt the empirically identified current best adaptation practice available locally. It is therefore, climate change adaptation-strengthening interventions should focus on factors that underly the locally-specific barriers to adaptation. In this case, climate change adaptation strengthening intervention for smallholders in the study area should be better targetted to female-, older-age-, and lower-educated headed households. Moreover, the intervention should focus more on activities that expose these households to climate change-related innovation and technology on the one side, and improve the household's access to credit, and hence financial resources, on the other side, through which the smallholder households gain sufficient capacity to adopt the empirically identified current best adaptation practice.

Furthermore, considering that the study has defined off-farm adapted households, as those who managed to diversify their livelihoods to off-farm employment, the identified six adaptation-determining factors could also be considered as the main determinants for the smallholders to engage in more diversified livelihoods, and hence generate more cash income. Previous studies indicated that, given a household's better access to innovation and technology, any increase in household's income is likely to contribute the household's better adoption of on-farm adjustments. However, given the critically limited availability of rice at household level to meet its minimum requirement, the increased income is also most likely being allocated to access the readily available source of rice for the poor, in this case the government program of *Raskin*. As already elaborated above, the off-farm adaptation has been proved to contribute more to the increase of the current HRSL, rather than stabilizing the HRSL to the future climatic conditions. This suggested that, given the limited amount of cash generated from off-farm employment, the off-farm adapted household is more likely to put the improved access to external source of rice as its first priority, rather than prioritizing the income for on-farm adjustment.

## 4. Conclusion

Climate change has exacerbated the rice insufficiency condition of smallholder farm households in the study area. The result of the study indicated that a reduction in annual average rainfall, in combination with an increase in minimal and maximal temperature to the near and far-future projections under both the RCP4.5 and RCP8.5, brought about a reduction in rice yield, and hence a decrease in household rice sufficiency level. The level of reduction in rice yield is highly sensitive to the diversity in current farming practices. The highest rice yield was generated by the farming practice of On-I3 for irrigated farming and by On-R1 for the rainfed, where under baseline period, the yield was recorded at 56.62 quintal/hectare and 41.30 quintal/hectare, respectively. Both farming practices, at the same time, also generated the most stable rice yield to the near- and far-future projection, as indicated by their lowest yield reduction, relative to that of the other farming parctices

The rice yield reduction impact of climate change affected the smallholder household's rice insufficiency level to the extent variable across different types of individual household's current autonomous adaptation responses. Among the four general types of adaptations identified, the combined on- and off-farm adapted group generated the highest HRSL, followed consequently by the off-farm and on-farm adapted group. Under baseline, the average HRSL of the three types of adaptations are recorded at 61.64%, 58.40%, and 56.12%, respectively, higher than that of the non-adapted which is 54.53%. In terms of resilience to future climate, the result of the study indicated that the combined on- and off-farm adapted households have been the most resilient group, as indicated by its lowest HRSL reduction, both to the near and far-future projection. Moreover, the on-farm adapted group indicated better resilience to changing climate than the off-farm adapted. Similar pattern in climate change-induced rice yield and its implication on household rice sufficiency level was shared between RCP4.5 and RCP8.5 for both near- and far-future projections.

The study identified six determining factors to smallholder households' decision on whether or not to adopt the empirically identified current best adaptation practice observed in the study area, i.e. the combined on- and off-farm adaptations.adoption. The factors involved the household head's gender, age and education, household's access to credit, size of farm plot, and distance of the farm plot to water irrigation reservoir. The result suggested that climate change adaptation-strengthening intervention to the study area should be better targetted to female-, older-age-, and lower-educated headed household. Moreover, the intervention should focus more on activities that expose these households to climate change-related innovation and technology on the one side, and improve the household's access to credit, and hence financial resources, on the other side, through which the smallholder households gain sufficient capacity to adopt the empirically identified current best adaptation practice. Furthermore, considering that the study has defined off-farm adapted households, as those who managed to diversify their livelihoods to off-farm employment, the identified six adaptation-determining factors could also be considered as the main determinants for the smallholders to engage in more diversified livelihoods, and hence generate more cash income to facilitate the households' improved on-farm adjustment, on the one side, and better access to external source of rice, on the other side.

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