

Original Research Article

Smallholder Farm Households' Vulnerability and Adaptation to Climate-Induced Food Insecurity

ABSTRACT The smallholders seem to have no alternative in addressing the climate-induced food insecurity, but to adapt their livelihood systems to the changing climatic conditions. Under current climate condition, most farm households in the study area are already insufficient in rice availability. With no adaptation, the current climate condition is likely to shift large portion of smallholder households to be rice-insufficient, or force those who are already insufficient to be severely insufficient. Further analysis indicated a link between the household food security level (HRSL) and the composite household vulnerability level (HVI). The higher the composite HVI is, the more likely the household to be rice insufficient or even rice severely insufficient. The study recognized five major determinants of HVI level, which involved, in sequence according to its score: "food" (0.53), irrigation (0.47), livelihood (0.45), knowledge (0.42), and finance (0.38). The score represents the factor's level of priority for intervention relative to the others. The application of the Intergovernmental Panel on Climate Change (IPCC)-vulnerability framework approach has revealed that adapted households typically have smaller overall IPCC-HVI than the non-adapted do. Furthermore, the combination of on-farm and off-farm adaptation brought about lower IPCC-HVI, relative to either the on-farm or off-farm adaptation did.

Key Words: Climate Change, Food Insecurity, Vulnerability, Adaptation

1. INTRODUCTION

Smallholder farm households in developing countries are typically vulnerable to climate-induced food insecurity, due to their limited capacity to adapt [1,2]. Though there is no unanimously agreed estimate on the portion of smallholders in the world's farms, most likely due to the lack of standardized definitions of the terms [3], all estimates worldwide indicated a huge portion, which ranged from 50% [4] to 85% [5]. In Indonesia, smallholder farm households constitute equally substantial portion, where the latest Farm Household Census reported a figure of around 55.95%, defined as those whose farmland size is less than 0.5 ha [6]. Taking the problem of huge portion into account, the impact of changing climatic condition on smallholder farmers has been a focus of attention worldwide.

Climate change is expected to further exacerbate the current numerous risks that smallholder farmers have already faced to their agricultural production, which often undermine their household food security condition [7]. Since farming is often the only livelihood on which most smallholders rely, any small reduction in agricultural yields is likely to worsen the already limited access of the smallholders to sufficient food [8]. Furthermore, the smallholders' limited resources and capacity to cope with the shocks made them highly vulnerable, and accordingly forced most of them to shift in and out of a state of undernourishment [9].

The smallholders seem to have no alternative to address the adverse impact of climate change on their food condition but to adapt their livelihood systems to the changing climatic conditions [10]. Substantial numbers of previous studies indicated that smallholder farmers have assumed autonomously some adaptation measures in their farming management practices, which range from simple adjustment on planting calendar to investment on input and infrastructure [11]. Referring back to their highly limited resources and hence capacity, the autonomous adaptation measures of the smallholders have yet to be optimal and still leave substantial residual impacts untapped [12]. This has been a key challenge for decision makers, policy makers, and development partners to understand the current adaptation measures of the smallholders in their efforts to address the adverse food insecurity implication of climate change.

In order to feed into the decisions on the design and implementation of adaptation strategies for responding to the adverse impact of climate change on food insecurity, researches have been growing in addressing the issue. In this connection, various research approaches, methods, and tools have been developed. The first approach was introduced by IPCC [13] known as Climate Change Impact, Adaptation, and Vulnerability (CCIAV). The development of this approach, as well as its methods and

tools, has been surprisingly fast, but tends to be partial. Impact study, on the one side, culminated in “top-down” approach [14] or “scenario-based” approach [15]. On the other side, vulnerability study led to bottom-up approach [14]. Meanwhile, in its recent development, adaptation has been incorporated into top-down approach to assess its efficacy in addressing the biophysical impact of climate change [16,17] and into bottom-up approach to address the vulnerability of a system to climate change [18,19]. Important critics pertinent to this approach have been dealing with integration of the top-down and bottom-up. Though at conceptual level, it has been adequately addressed by the fast development of integrated approach [20], at methodological level, however, the progress has been very limited.

The study integrates the concept of impact, vulnerability, and adaptation to assess the climate-induced food insecurity and vulnerability level, and the link between the two in shaping adaptation response of the smallholders under current climate condition. In specific, the study aims to assess (i) the current climate-induced food insecurity level of farm households, as represented by the current households’ rice sufficiency level (HRSL), (ii) the current vulnerability level of farm households, as represented by household vulnerability index (HVI), (iii) the extent to which the household vulnerability level determine the HRSL, and (iv) the extent to which adaptation has been effective to reduce household vulnerability level to climate-induced food insecurity.

2. MATERIALS AND METHODS

2.1. Study Area

The study was conducted in Ujungjaya Sub district, the District of Sumedang, West Java Province, Indonesia. The study area cover all the nine villages available in Ujung Jaya, namely Cibuluh, Cipelang, Keboncau, Kudangwangi, Palabuan, Palasari, Sakurjaya, Sukamulya, and Ujungjaya. 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. Ujungjaya Sub-district covers a landmass of 8,056 ha, where agriculture occupies 2,637 ha or around 32.73%. According to its water supply, farming is divided into rain-fed, whose water supply is exclusively derived from rainfall, occupying 1,946.5 ha or 73.81%; and the remaining 26.19% are irrigated, whose water supply is supplemented and/or regulated by irrigation infrastructure. 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 [21].

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. 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 [22], where around 37.44% fall into poor household category based on indicators developed by Social Protection Programs [23]. Majority of the people (72.68%) are farmers.

Farming calendar generally follows the pattern of rainfall. In the rain-fed areas, planting is generally made 2 times a year. The first planting links to the onset of rainy season (usually in November or December), 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.

In irrigated areas, planting time is relatively more flexible, made possible by supplementary water supply from irrigation. Planting occurs at almost every month, though the general pattern still follows that of the rainfall (Figure 1). Delay in planting time is relatively common in the study area, in relation to the onset of rainy season. There are at least two main reasons for the delay in planting. The first is limited labor. The phenomenon of decreasing interest of the youth on farming is already observed in the study area. The youths generally move to urban areas for off-farm employments, leaving the old to grapple with farming. The second links to water availability at farm plots level, determined mainly by access to water reservoir. Land preparation for planting requires large amount of water. For those farmers whose farm plots are close to 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.

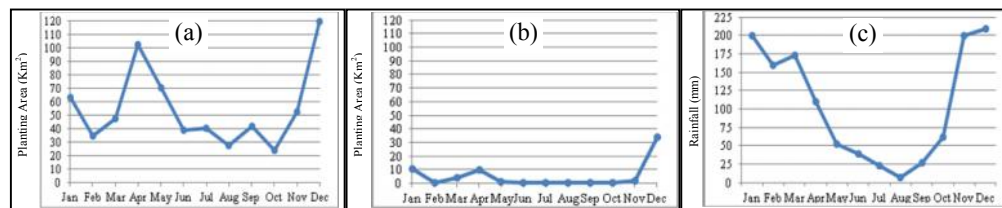


Figure 1. Planting calendar of irrigated (a) and rain-fed farm (b), in relation to rainfall pattern (c). Source: Annual report of planting area for 2012 [24].

According to the local practices, planting rice generally starts with raising the seedlings in a nursery and later transplanting them in the main field. Small numbers of farmers also do direct planting, where seeds are drilled directly to zero tilled land, but this practice is only limited to dry-season planting. 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.

Irrigation is generally applied on a rotational-based, with an 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 might be supplemented with water pumps. But, this is only possible for famers who own adequate resources, while those who cannot afford the pumps just rely exclusively on rainfall. These variations in the onset of planting time and irrigation schedule among farmers reflect their autonomous responses to changes in local climate, which is highly determined by their capital.

2.2. Sampling

Sample households were calculated using the following formula:

$$n = \frac{Z_{1-\alpha/2}^2 p(1-p)N}{d^2(N-1) + Z_{1-\alpha/2}^2 p(1-p)}$$

Where:

n = Number of minimum sample required

α = Confidence interval (95%)

$Z_{1-\alpha/2} = 1.96$

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 [23].

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 was collected through interview using questionnaire with the head and housewife of sample households, combined with Focus Group Discussion (FGD) with key informants, and field observation. Data collected involved: (i) household's rice production system that involve 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 characteristics to explore factors determining the household vulnerability and adaptation to climate-induced food insecurity.

2.4. Data Analysis

Data analysis referred to the new IPCC concept of impact, adaptation, and vulnerability assessment [12]. The new IPCC concept used the term "impact" primarily to refer to the effects on natural and human systems of climate change. In the context of this study, impact is represented by climate-induced food insecurity at household level. Meanwhile, the term "vulnerability" refers to the propensity or predisposition to be adversely affected. In this study, vulnerability was quantified as household vulnerability index. Finally, the term "adaptation" represents the process of adjustment in natural and human systems in response to actual or expected climate and its effect, which moderates harm or exploits beneficial opportunities [25]. Here, three types of adaptation were identified and their efficacy to reduce vulnerability was assessed.

2.4.1. Calculation of Household Rice Sufficiency Level

The study used HRSL as an indicator to measure food insecurity at household level. The HRSL was calculated as the ratio of the actual availability to the minimum requirement of rice at household level to meet the minimum requirement of calorie for a healthy and active life of all the household members. The standard calorie requirement of 2,000 kcal/capita/day [26] was used to calculate the annual minimum requirement of rice at household level (HRR) using the following formula:

$$HRR = p \times 2400 \times c \times h \times 365 \text{ (Kcal/Household/Year (equation 2)}$$

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 contain 360 kcal [27]

h = Number of household members

On the other side, the annual actual availability of rice at household level (HRA) was assessed using the following formula:

$$HRA = \sum_{i=1}^n (y_i \times l_i) - (c + s) + np \text{ (equation 3)}$$

Where:

y = Yield (in ton GKP /ha)

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 (ton GKP) allocated to cover cost of production (wage, seed, rent, etc.)

s = Portion of harvest (ton GKG) sold for purposes other than cost of production

np = Food from sources other than households' own farm production (e.g. assistance, purchased, borrowed)

The HRSL was calculated as the ratio of HRA to HRR, indicating the degree to which a household is able to attain its sufficiency level in rice. The higher the HRSL is the better the capability of a household to meet its rice sufficiency. The HRSL was calculated individually for each sample household using individual household data generated from household survey. Afterward, the average HRSL of the whole sample was calculated to represent the magnitude of the current food insecurity level in the study area.

The average HRSL was also calculated for splitted groups of sample households based on the types of adaptation they develop to address the current climate-induced food insecurity. The splitted groups involve the followings:

1. On-farm adapted group covers those households who had made on-farm adaptations that involve (i) shifting planting time to better match the current rainfall pattern and (ii) improving irrigation schedule through investment on irrigation infrastructure, in particular water pumping and piping. This group represents households whose current planting time and irrigation scheduling generated highest yield, relative to the others did.
2. Off-farm adapted group covers those households who had better access to rice from sources other than own farm production, in this case access to government-subsidized rice (Rice for the poor/Raskin program). The off-farm adapted are those who manage to access at least 10 kg raskin, out of the total 15 kg allocated for each poor household per month. This group is characterized by diversified livelihoods to off-farm employments, which guarantee more stable income.
3. Combined on- and off- farm adapted group covers those households who had made both on- and off adaptations.
4. Non-adapted group covers those households who had made neither on- nor off-adaptations.

A comparison was then made accordingly between the adapted-groups and non-adapted group to provide an indication on the extent to which the current climate has affected the food security of individual farm household and an indication on the efficacy of current adaptation practices adopted by individual farm household to address the current climate impact.

2.4.2. Calculation of Household Vulnerability Index

The study used two different approaches, i.e. composite index approach and IPCC-framework approach [18, 28, 29]. The composite index was designed to understand the various factors determining the vulnerability level of farm households to climate-induced food insecurity. Meanwhile, the IPCC-framework approach was applied to explain the link between the level of vulnerability and adaptation of the farm households to climate-induced food insecurity.

The composite index was calculated using balanced weighted average of the five major components, which involved (1) Irrigation water, (2) Knowledge, (3) Food, (4) Finance, and (5) Livelihood. Each consists of several indicators (sub components) representing the current vulnerability and adaptation to climate-induced food insecurity at household level, as presented on Table 1.

Table 1. The components of household vulnerability

Vulnerability Components	Sub-Components	Elaboration and Scoring of the Sub-Components
Irrigation water	Distance from households' farm plot to irrigation reservoir	The shorter the distance, the lower the score, and the better the irrigation. Scoring: (1) < 0.5 km; (2) 0.5 s/d 1.0 km; (3) > 1.0 km
	Method(s) to access irrigation reservoir	The better the method(s), the lower the score, and the better the irrigation. Scoring: (1) canal, piping, and water pumping, (2) canal and piping, (3) canal, (4) rely on rainfall
Knowledge	Education of household head	The higher the education, the lower the score, and the better the knowledge. Scoring: (1) More

		than High School; (2) High School; (3) Junior School; and (4) Elementary School or less
	Involvement in farmer group activities	Those who involved will get lower score, and be better in knowledge. Scoring: (1) Involved; and (2) Not involved
Food	Percentage of food from own-farm production	The lower the percentage, the lower the score, and the better the food condition. Scoring: (1) < 50%; (2) 50-60%; (3) > 60%
	Number of months a household having difficulty to access food	The less the numbers, the lower the score, and the better the food condition. Scoring: (3) < 3 months; (2) 3-4 months; and (1) > 4 months
Finance	Ownership of livestock	Those who owned will get lower score, and be better in finance. Scoring: (1) Owned; and (2) Not Owned
	Access to credit	Those who have access will get lower score, and be better in finance. Scoring: (1) Received credit at least once and (2) Never received credit (during the last 5 years)
Livelihoods	Diversification in livelihoods	The more diversified the livelihood, the lower the score, and the better the livelihood. Scoring: (1) Farming, farm labor, with/without livestock, and off-farm labor; (2) Farming, farm labor, livestock; and (3) Farming & farm labor

Since each of the vulnerability sub components was measured in a different scale, there is a necessity to standardize the score of each sub component as an index (I_{sc}) by using the following formula:

$$I_{sc} = \frac{S_{sc} - S_{scmin}}{S_{scmax} - S_{scmin}}$$

Where, S_{sc} is the actual score, while S_{scmin} and S_{scmax} represent the minimum and maximum score of sub component, respectively. The standardized sub components' score (I_{sc}) of each vulnerability component were then averaged to generate a standardized score of each vulnerability component (I_c). Based on which, the HVI was calculated as an average of the whole vulnerability components.

Under the IPCC framework, the various vulnerability sub components were group into the IPCC three major components of vulnerability, which involved exposure, sensitivity, and adaptive capacity [30]. Exposure has been defined as the degree of climate stress upon a particular unit of analysis, and may be represented as either long-term change in climate condition, or by changes in climate variability, including the magnitude and frequency of extreme events. Meanwhile, the term sensitivity represented the degree to which a system will be affected by, or responsive to climate stimuli. Adaptive capacity is the potential or capability of a system to adjust to climate change, including variability and extreme, so as to moderate potential damages, to take advantage of opportunities, or to cope with consequences.

The re-categorization of vulnerability sub components into the three IPCC vulnerability factors was presented on Table 2. The first step in calculating the IPCC-vulnerability index is to calculate the standardized score for each of the IPCC-vulnerability factors (exposure, sensitivity, and adaptive capacity) by balanced weighted averaging the standardized score of its component indicators. The IPCC-vulnerability index was then calculated using the following formula:

$$PCC - Vulnerability Index = (I_e - I_{ac}) * I_s$$

Where I_e , I_{ac} , and I_s are standardized score of exposure, adaptive capacity, and sensitivity, respectively.

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280 Table 2. The scoring of IPCC-vulnerability components.

IPCC-Vulnerability Factors	Component Indicators
Exposure	Distance from households' farm plot to irrigation reservoir Method(s) to access irrigation reservoir
Sensitivity	Percentage of food from own-farm production Number of months a household having difficulty to access food
Adaptive Capacity	Education of household head Ownership of livestock Involvement in farmer group activities Access to credit Diversification in livelihoods

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282 The HVI (both composite and IPCC) was calculated individually for each sample household using
 283 individual household data generated from household survey. Afterward, the average HVI of the whole
 284 sample was calculated to represent the magnitude of the current household vulnerability level to climate-
 285 induced food insecurity in the study area. The average composite-HVI was also calculated for splitted
 286 groups of sample households based on the level of households' rice sufficiency in order to assess the
 287 extent to which the household vulnerability level determine the HRSL. The splitted groups involve the
 288 followings: (1) Rice-sufficient group covers those households whose RSL is equal to or more than 90%,
 289 (2) Rice-insufficient group cover those households whose RSL range from 70% to 89.99%, and (3) Rice-
 290 severely insufficient group covers those households whose RSL is less than 70%. The analysis of splitted
 291 group was also made for IPCC-HVI, where the sample households were splitted according to household's
 292 type of adaptation, as already elaborated above. This is made in order to assess the extent to which
 293 adaptation has been effective to reduce household vulnerability level to climate-induced food insecurity.
 294 In this study, the HVI was scaled from -1 (least vulnerable) to 1 (most vulnerable).

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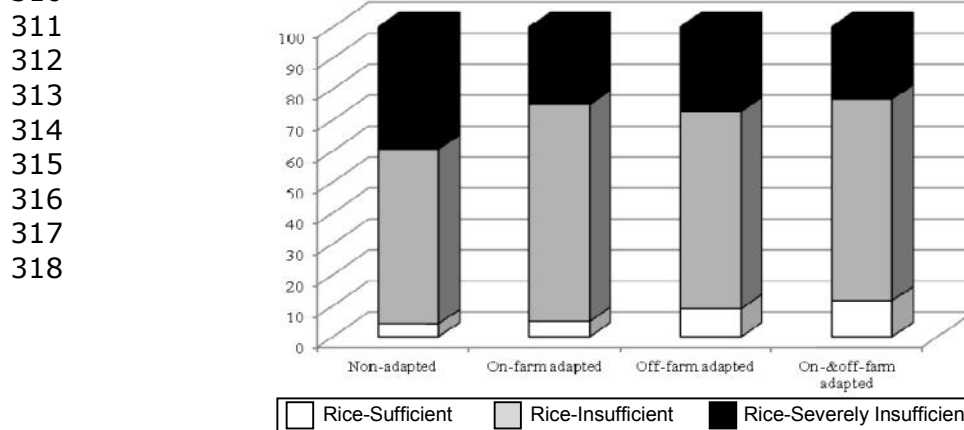
296 3. RESULTS AND DISCUSSION

297 3.1. Farm Households' Food Insecurity Level under Different Types of Adaptation

298 The result of the study showed that out of the 156 sample household, only 7.05% have been
 299 sufficient in rice, while the remaining 61.54% and 31.41% are still insufficient and severely-insufficient,
 300 respectively. This finding suggested that under current climate condition, most farm households (92.95%)
 301 in the study area are already lack of capacity to bring sufficient quantity of rice for their family to fulfill the
 302 minimum calorie availability at household level required for ensuring a healthy and active life. It also
 303 implied that with no adaptation, the current climate condition is likely to shift large portion of households to
 304 be rice-insufficient, or force those who are already insufficient to be severely insufficient. This finding is
 305 consistent with the result of similar study in the Nile Basin of Ethiopia [31].

306 The study also identified, as indicated on Figure 2, that a household capacity to ensure its sufficiency
 307 in rice has been linked to different types of adaptation it has developed to cope with the climate-induced
 308 reduction in rice yield from its own farm plot. Three types of adaptation have been identified, which
 309 involved on-farm adaptation, off-farm adaptation, and the combination of on- and off-farm adaptation.

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Figure 2. The proportion of sample households (%) according to different level of rice sufficiency, under different types of adaptation

Figure 1 showed that on-farm adaptation brought about smaller portion of households who are severely insufficient in rice than the off-farm adaptation did (25.00% vs. 27.27%). However, the portion of rice-sufficient households is slightly larger among the off-farm than that among the on-farm adapted (9.09% vs. 5.00%). The combination of the on-farm and off-farm adaptation resulted in larger portion of rice-sufficient (11.63%) and smaller portion rice-severely insufficient households (23.26%) than either the on-farm or off-farm adaptation did. In general, the study generated an impression that adaptations have shifted some portion of households from rice-severely insufficient to rice-insufficient group and further from rice-insufficient to rice-sufficient group. However, the portion of those who shifted from insufficient to sufficient group is substantially smaller than those shifted from the severely insufficient to insufficient group.

One plausible argument to justify the above findings is the limmited contribution of on-farm adaptation to improved HRSL because the minimized rice yield reduction impact of the on-farm adaptation to increased rice production is confined to the yield potencies of the rice variety grown and the extremely limited size of land per household, which range from only 0.03 ha to 0.06 hectar. Therefore, this type of adaptation seems to be only sufficient to shift substantial portion of households from “severely-insufficient” to “insufficient”, but not from “insufficient” to “sufficient” group. Another argument would be the fact that off-farm adaptation provided additional cash income to farm household, which resulted in increased household’s economic access to sources of rice other than household’s own farm production. When it is combined with improved physical access to rice, made possible by government subsidized rice program (Raskin), the off-farm adaptation would be effective to shift larger portion of households who are already in “rice-insufficient group” further to “rice-sufficient group”. Those arguments were in line with the results of previous studies [32,33,34], which suggested that one single adaptation was likely to be inadequate, and hence diversity of adaptation measures are required to address the impact of changing climate adequately. Furthermore, it is confirmed previous study that a substantial increase in food production is not sufficient to ensure food security, unless it is accompanied by increased access to adequate and nutritious food and capacities to cope with climate-induced food insecurity[35].

3.2. Farm Households’ Vulnerability to Different Level Food Insecurity

The study defined five major components of vulnerability, representing current condition in the study area that determine the overall farm household vulnerability level to climate-induced food insecurity. Those components involved food, irrigation, livelihood, knowledge, and finance. The study indicated a link between HRSL and the composite HVI, where rice-sufficient households have relatively lower HVI (0.39) than the insufficient (0.46) and severely-insufficient households (0.54). The finding sugested that the more vulnerable a household, or in this case the higher the HVI, the more likely the household to be rice insufficient or even rice severely insufficient. This finding is consistent with previous study, which confirmed that at macro level, the high income nations are most likely to adapt, and the most vulnerable are least likely to adapt [36].

Further analysis was also made to assess the extent to which each of the five vulnerability components has contributed to the overall household vulnerability level and the result is presented on

Figure 3.

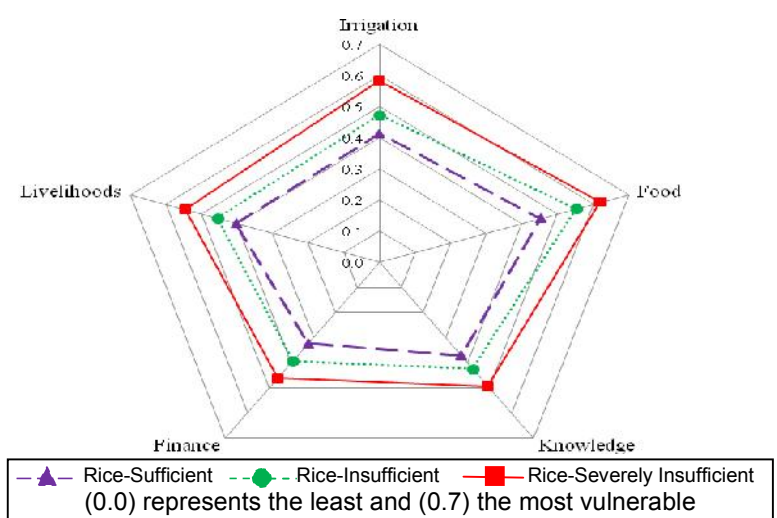


Figure 3. The spider diagram of the major components of vulnerability under different level of household rice sufficiency.

Figure 3 showed that rice-severely insufficient households are typically those who are most vulnerable in terms of all the five vulnerability components. Any integrated interventions that reduce simultaneously the score of the five components are likely to shift a household from rice-severely insufficient to rice-insufficient, and further to rice-sufficient group. The figure also indicated the level of significance of one vulnerability component relative to another in determining the overall vulnerability level of a household. The higher the score of a component, the more significance is its contribution to the overall vulnerability.

The study revealed that “food” component has the highest score (0.53) and followed consecutively by irrigation (0.47), livelihood (0.45), knowledge (0.42), and finance (0.38). This indicated that rice sufficiency level of a household in the study area is most sensitive to changes in the condition of the food component. Therefore, any intervention that improves food condition of a household is most likely to reduce the overall vulnerability level of the household, to the extent relatively higher than that addressing any of the other vulnerability components did. The study recognized at least two critical areas for intervention to improve household food condition, i.e. high dependence of most households on rice from own farm production and high incidence of households’ facing difficulties to access food, in terms of both economic and physical access. Interventions that address those two areas are most likely to reduce the score of food component, and hence the level of overall vulnerability.

The second major component is irrigation, which represents condition underlying farm households’ access to irrigation water for their farm plot. There are at least two main factors that determine farm households’ access to irrigation water for their farm plot, i.e. distance to water irrigation reservoir from households’ farm plot and households’ method(s) to access the reservoir. A shorter distance combined with better method will most likely to result in a smaller score of irrigation component, and hence a lower overall vulnerability level. This suggested that any intervention to improve irrigation water supply to households’ farm plot in the study area should take these two major factors into consideration.

The remaining three major components (knowledge, finance, and livelihood) seem to have a strong link one to another. The knowledge component determined a household’s access to innovation and technology, and when combined with the household’s better financial resources and more diversified livelihoods, will result in the household’s better capacity to adapt by ensuring better adoption of innovation and technology. This, in turn, will ensure a minimized climate induced reduction in rice yield, leading to increased rice production and hence reduce the overall household’s vulnerability to climate-induced food insecurity.

Overall, it is also justified to infer that the score of a vulnerability component represents its priority level for intervention relative to the others. In this case, the study suggested that the first priority area for any intervention to address farm household vulnerability to climate-induced food insecurity in the study area is the food condition, and followed by irrigation, livelihoods, knowledge, and finance.

3.3. Farm Households' Vulnerability and Adaptation to Food Insecurity

The study applied the IPCC-vulnerability framework approach to assess the extent to which adaptation has been effective to reduce the household vulnerability level to climate-induced food insecurity in the study area. The result of the study indicated that adapted households typically have smaller overall IPCC-HVI than the non-adapted do. The IPCC-HVI of the on-farm adapted households is recorded at -0.11, substantially lower than either the non-adapted (+0.11) or the off-farm adapted (-0.03). The combination of on-farm and off-farm adaptation brought about the lowest IPCC-HVI, which is recorded at -0.12.

Further analysis, as presented on Figure 4, suggested that the non-adapted households are typically those with highest score in exposure (0.62) and sensitivity (0.64), but the lowest score in adaptive capacity (0.44). On-farm adaptation reduced the score of exposure to a level relatively lower (0.40) than the off-farm adaptation did (0.48). In the context of this study, on-farm adaptation reduced the probability of a farm household to be affected by climate-induced reduction in rice yield through improved access to water irrigation. Meanwhile, the lower contribution of off-farm adaptation is justified by its typical nature of indirect contribution in that, as already elaborated above, increased financial resources from off-farm adaptation can contribute only to better adoption of innovation and technology, unless it is accompanied by better access to knowledge and information.

Off-farm adapted households had relatively lower score of sensitivity (0.39) than the on-farm adapted did (0.55). Lower sensitivity score, in this context, represents lower dependence on rice from own farm production. Off-farm adaptation suggested more diversified livelihoods that lead to increased off-farm income. Therefore, off-farm adapted households are most likely to have better economic access to various sources of rice other than their own farm production. This will lead to reduced dependence on subsistence rice and ensure more stable access to rice, and hence ensure lower sensitivity score for off-farm adapted households.

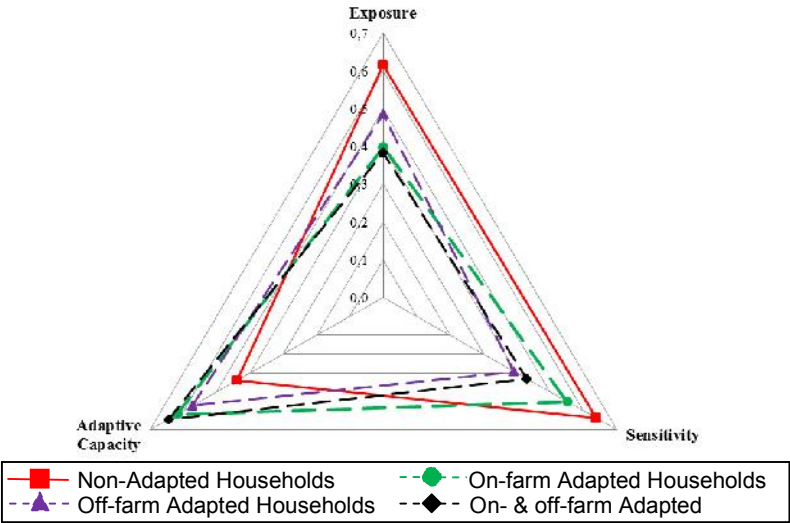


Figure 4. The triangle diagram of the IPCC-three components of vulnerability (Exposure, Sensitivity, and Adaptive Capacity) under different types of adaptations.

The combination of on- and off-farm adaptation brought about higher score of adaptive capacity for the adapted group (0.64), relative to either the on-farm or off-farm adaptation did (0.44 and 0.57, respectively). Adaptations are the manifestations of adaptive capacity [37]. It is therefore, the study suggested that the higher the adaptive capacity score of a household, the better its capacity is to pursue various types of adaptations.

The study identified at least five major factors determining adaptive capacity score. One of which, as already confirmed by [38] is the availability of alternative livelihoods, while the other four major factors are access to credit, involvement in farmer group activities, ownership of livestock, and education of household head.

4. CONCLUSION

Under current climate condition, most farm households in the study area are already insufficient in rice availability. The result of the study implied that with no adaptation, the current climate condition is likely to shift large portion of households to be rice-insufficient, or force those who are already insufficient to be severely insufficient. Further analysis indicated a link between HRSL and the composite HVI. The more vulnerable a household, or in this case the higher the composite HVI, the more likely the household to be rice insufficient or even rice severely insufficient. The rice-sufficient households have relatively lower HVI (0.39) than the insufficient (0.46) and severely-insufficient households (0.54).

The study defined five major components of vulnerability determine the overall farm household vulnerability level to climate-induced food insecurity. Those components involved food, irrigation, livelihood, knowledge, and finance. The study revealed that “food” component has the highest score (0.62) and followed consecutively by irrigation (0.55), knowledge (0.49), and finance (0.46). This score represents its level of priority for intervention relative to the others. In this case, the study suggested that the first priority area for any intervention to address farm household vulnerability to climate-induced food insecurity in the study area is the food condition, and followed by irrigation, livelihoods, knowledge, and finance.

The application of the IPCC-vulnerability framework approach to assess the extent to which adaptation has been effective to reduce the household vulnerability level has revealed that adapted households typically have smaller overall IPCC-HVI than the non-adapted do. The IPCC-HVI of the on-farm adapted households is recorded at -0.11, substantially lower than either the non-adapted (+0.11) or the off-farm adapted (-0.03). The combination of on-farm and off-farm adaptation brought about the lowest IPCC-HVI, which is recorded at -0.12.

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