



## Research article

# Assessment of smallholder farmers' adaptive capacity to climate change: Use of a mixed weighting scheme

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## ABSTRACT

Weighting scheme definition represents an important step in assessment of adaptive capacity to climate change with indicator approach since it defines the trade-offs among indicators or components and can be source of uncertainty. This study aims to assess smallholder farmers' adaptive capacity to climate change by using a mixed weighting scheme that reflect farmers' perceived importance of adaptive capacity components to inform policy makers. To achieve that objective, the sustainable livelihood framework was adopted and indicator approach was used for the assessment. The mixed weighting scheme were defined by using both equal weights and experts judgement methods during the assessment process. The mixed weighting scheme index is compared to the case where equal weights are applied in the assessment process and an uncertainty analysis was performed on relative standard deviation through a Monte Carlo simulation. Primary Data were collected from 450 farmers in two communities in northern Benin with a structured questionnaire and through focus groups discussion. The results show that smallholder farmers in both communities do not have the same perceived importance of adaptive capacity components. The index scores show that farmers have in majority low adaptive capacity. When weighted product aggregation method is used, there is more uncertainty related to the index computed with the mixed weighting scheme, but it leads to the same characterisation when compared with the index computed with the equal weights. It is recommended that mixed weighting scheme should be preferred for the assessment of adaptive capacity and weighted product aggregation method should be used.

## 1. Introduction

Assessment of adaptive capacity to climate change has received great attention from scholars and policy makers last decade because of the necessity for both developing and developed countries to reduce the negative impact of climate change through adaptation. The aims of these attention were to define the concept (Hinkel, 2011; Smit and Wandel, 2006; Yohe and Tol, 2002), provide framework, methods and tools for its assessment (Adger and Vincent, 2005; Brooks et al., 2005; Bryan et al., 2015) to better inform adaptation policy. Adaptive capacity is one of the important factors that define vulnerability to climate change (Adger et al., 2007; Engle, 2011; Gallopín, 2006) and its assessment represents an important step in vulnerability evaluation and provides means to develop adaptation policy since factors that underlies and enables adaptation activities are analysed (Adger et al., 2007; Juhola and Kruse, 2013). Adaptive capacity is generally defined as ability of a

system to adjust to a current or future threats (Smit and Wandel, 2006). Because of the nature of adaptive capacity which is latent and does not have indicator to measure it (Engle, 2011; Engle and Lemos, 2010), composite indices are generally used to quantify and characterise the concept. The use of composite indices to evaluate adaptive capacity requires for aggregation a weighting scheme to highlight the relative importance of sub-components (Gan et al., 2017; Nardo et al., 2005). Moreover, when there is some compensation among components used to define adaptive capacity, weighting scheme can express the trade-off ratios among the dimensions (Böhringer and Jochem, 2007). Thus, inappropriate definition of weighting scheme can make adaptive capacity index misleads vulnerability assessment and then adaptation policy (Gan et al., 2017). However, during index development there is generally no information on components or indicators contribution to the final index that are defined. That leads to a definition of weighting scheme which does not reflect the importance of each sub-components

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and constitute a source of uncertainty for the composite index (Burgass et al., 2017; Marzi et al., 2018).

Methods generally use to define weights for composite indices to assess adaptive capacity to climate change can be grouped into three categories: equal weighting, data driven weighting and experts' opinion-based weighting (Gan et al., 2017; Nardo et al., 2005). Although, there is no agreement among scholars on which methods seems the best, equals weighting represents the most used method because of its simplicity and ability to give the same level of importance to each component (Greco et al., 2019). However, this might reveal the lack of knowledge on the importance of components to the final index or the causal relationship among indicators (Nardo et al., 2005; Wang and Fu, 2019). For data driven weighting methods, weights are derived based on statistical tools which rely on characteristic of data and correlation analysis to help avoid double counting. However, this could lead to a missing of important variables who are correlated and definition of inappropriate composite indicator since weights are based on values and may not highlight the importance of information variables conveyed (Gan et al., 2017; Greco et al., 2019). Equals and data driven weights definition methods may mislead policy intervention if the composite index been measured is to capture information at individual level such as farmers' adaptive capacity to climate change where weights have to reflect farmers' perceived importance of each components to inform policy makers. By contract, experts' opinion weighting methods which define weights based on value judgment of experts can be appropriate to define weights for composite index at individual level if theirs results were not subject to the number of indicators assessed (Greco et al., 2019; Nardo et al., 2005).

Empirical studies that assessed smallholder farmers' adaptive capacity to climate change with indicator approach generally formulate policies interventions to improve only components of adaptive capacity that have low score (Abdul-razak and Kruse, 2017; Egyir et al., 2015). In so Doing, they do not exploit information provided by the weighing scheme and may fail to have farmers' adhesion to the policy. Moreover, in a context of developing countries where policy makers have limited resources for interventions, all components of adaptive capacity could end up with low scores. Choice have to be made on which component to prioritise for policy intervention to have support of farmers.

In Benin, like most west African country, the agricultural sector contributes up to 30% of GDP and employs nearly 75% of labour force (INSAE, 2012; PAM, 2009). Agricultural production depends heavily on rainfall and is characterized by smallholder farmers who farm on average 1.7 ha of land (MAEP, 2011). Challenges facing the agricultural sector include access to markets, low use of production inputs and soil infertility (MAEP, 2011; PAM, 2009). The sector is also affected by climate change which is observed through high concentration of rainfall over a short period, fluctuation of the onset and duration of rainfall season, drought, floods, decrease in rainfall and increased of temperature (Boko et al., 2012). In fact, it was observed an increased in the average temperature by more than 1 °C and a decrease in the average rainfall by 5.5 mm per year between 1960 and 2008 (Gnanglè et al., 2011). Climate simulation studies by the horizon of 2100 indicate that temperature could increase between +2.6 °C and +3.2 °C and the northern part of Benin will experience a decrease in rainfall between 13% and 15% (MEHU, 2011).

The northern part of Benin, which represents the basket of foods and crops, plays an important role in the country's food security and majority of dwellers livelihood in this area depends on agriculture (Yegbeme et al., 2013). Assessments of the impact of climate change reveal that the northern Benin is the most vulnerable agro-ecological area to climate change and has been affected by all extreme climatic events that occurred in Benin from 1984 to 2010 (Boko et al., 2012; MEHU, 2011; Yabi and Afouda, 2012). There is therefore a need to design and implement policies that support smallholder farmers in northern Benin to reduce their vulnerability to climate change. However, policies to support farmers to reduce their vulnerability to climate change requires

information on farmers' adaptive capacity so that adaptation option that will be proposed could be easily adopted by farmers and will not lead to maladaptation among farmers due to lack of adaptive capacity.

In order to assess farmers' adaptive capacity to climate change using a composite index with a weighting scheme that reflect farmers' perceive importance of each components, we use a mixed method that combine equal weight and expert judgment methods to define weights. The equal weight method is applied during aggregation of indicators to obtain components because of its simplicity for application and ability to deal with a large number of variables while the experts' judgement is used to determine weight that is applied to each component for aggregation into a composite index. Specifically, budget allocation method is used to reveal farmers' perceived importance of adaptive capacity components during a focus groups using farmers as experts. The index obtained is useful for policy implementation because it gives the current level of adaptive capacity and also which components policy intervention should prioritise regardless of the values of the sub-component. The efficiency of the mixed weighting method is assessed through an uncertainty analysis using Monte Carlo simulation and compared with the case where equal weight method is used through the hall process.

## 2. Methods

### 2.1. Choice of indicators

Indicators approach is adopted to assess smallholder farmers' adaptive capacity. However, the theory-driven approach was adopted and the sustainable livelihood framework (Ellis, 2000; Scoones, 1998) is followed to define the components of farmers' adaptive capacity to climate change. In this context, farmer's adaptive capacity represents a stock of capital available to formulate his adaptations strategies to climate change within an institutional context with the purpose to achieve a sustainable livelihood. Like previous studies on adaptive capacity at household or individual levels (Bryan et al., 2015; Defiesta and Rapera, 2014; Ruiz Meza, 2015; Shah and Dulal, 2015), the five capitals (social, human, physical, natural and financial) essentials for a sustainable livelihood are used as components of farmers' adaptive capacity since they can determine actions a farmer can undertake against climate change impact within a policy and institutional context (Scoones, 1998). Indicators for each components were selected following the theory-driven approach and empirical studies on assessment of adaptive capacity to climate. A total of twenty-one indicators were used to assess smallholder farmers' adaptive capacity as summarised in Table 1.

### 2.2. Data analysis

#### 2.2.1. Normalization of indicators

Indicators selected were normalised before indices were computed because they do not have the same measurement unit and cannot be aggregated. Zhou, Ang, and Poh (2006), approach was used to normalise indicators to satisfy "the larger the better" interpretation. Let  $V_{ijk}$  be a variable representing indicator  $k$  of  $j$ th component of adaptive capacity for the  $i$ th individual and let  $x_{ijk}$  be the observed measurement of that indicator. The normalization was done using equation (1) where  $r_{ijk}$  is the resulting measure after transformation.

$$r_{ijk} = \begin{cases} \frac{x_{ijk}}{\max_i \{x_{ijk}\}} & \text{if } V_{ijk} \text{ satisfies "the larger the better"} \\ \frac{\min_i \{x_{ijk}\}}{x_{ijk}} & \text{if } V_{ijk} \text{ satisfies "the smaller the better"} \end{cases} \quad (1)$$

#### 2.2.2. Mixed weighting schemes definition

Two weights schemes were used to combine indicators into composite index, equal weight and expert judgement. At the first stage, the

**Table 1**  
Components and indicators of farmers' adaptive capacity to climate change.

	Components of adaptive capacity	Indicators of components	Supporting sources
Adaptive capacity to climate change	Social capital	<ul style="list-style-type: none"> <li>- Member of FBO</li> <li>- Number of relatives in the community</li> <li>- Participation to community activities</li> </ul>	Jacob et al. (2015); Ruiz Meza (2015); Egyir et al. (2015); Bryan et al. (2015); Lockwood et al. (2015); Abdul-razak and Kruse (2017)
	Human capital	<ul style="list-style-type: none"> <li>- Year of schooling</li> <li>- Experience in agriculture</li> <li>- Number of crops grown</li> <li>- Visits of extension services</li> </ul>	Yohe and Tol (2002); Jacob et al. (2015); Gbetibouo et al. (2010); Ruiz Meza (2015); Defiesta and Ropera (2014); Lockwood et al. (2015); Bryan et al. (2015).
	Physical capital	<ul style="list-style-type: none"> <li>- received a training in agriculture</li> <li>- total area cropped</li> <li>- distance house to farm</li> <li>- distance house to market</li> <li>- distance house to financial institution</li> <li>- distance house to extension services office</li> </ul>	Jacob et al. (2015); Ruiz Meza (2015); Defiesta and Ropera (2014); Bryan et al. (2015); Juhola and Kruse (2013)
	Natural capital	<ul style="list-style-type: none"> <li>- Rainfall variability</li> <li>- soil Fertility</li> <li>- Land ownership</li> <li>- Experienced with natural hazard events on farm</li> </ul>	Jacob et al. (2015); Ruiz Meza (2015); Egyir et al. (2015); Dannevig et al. (2015); Bryan et al. (2015)
	Financial capital	<ul style="list-style-type: none"> <li>- Off farm Income</li> <li>- value of livestock</li> <li>- crop income</li> <li>- value of agricultural equipment</li> <li>- Credit sources diversification</li> </ul>	Ruiz Meza (2015); Defiesta and Ropera (2014); Gbetibouo et al. (2010); Bryan et al. (2015); Lockwood et al. (2015); Jacob et al. (2015)

Source: Authors compilation

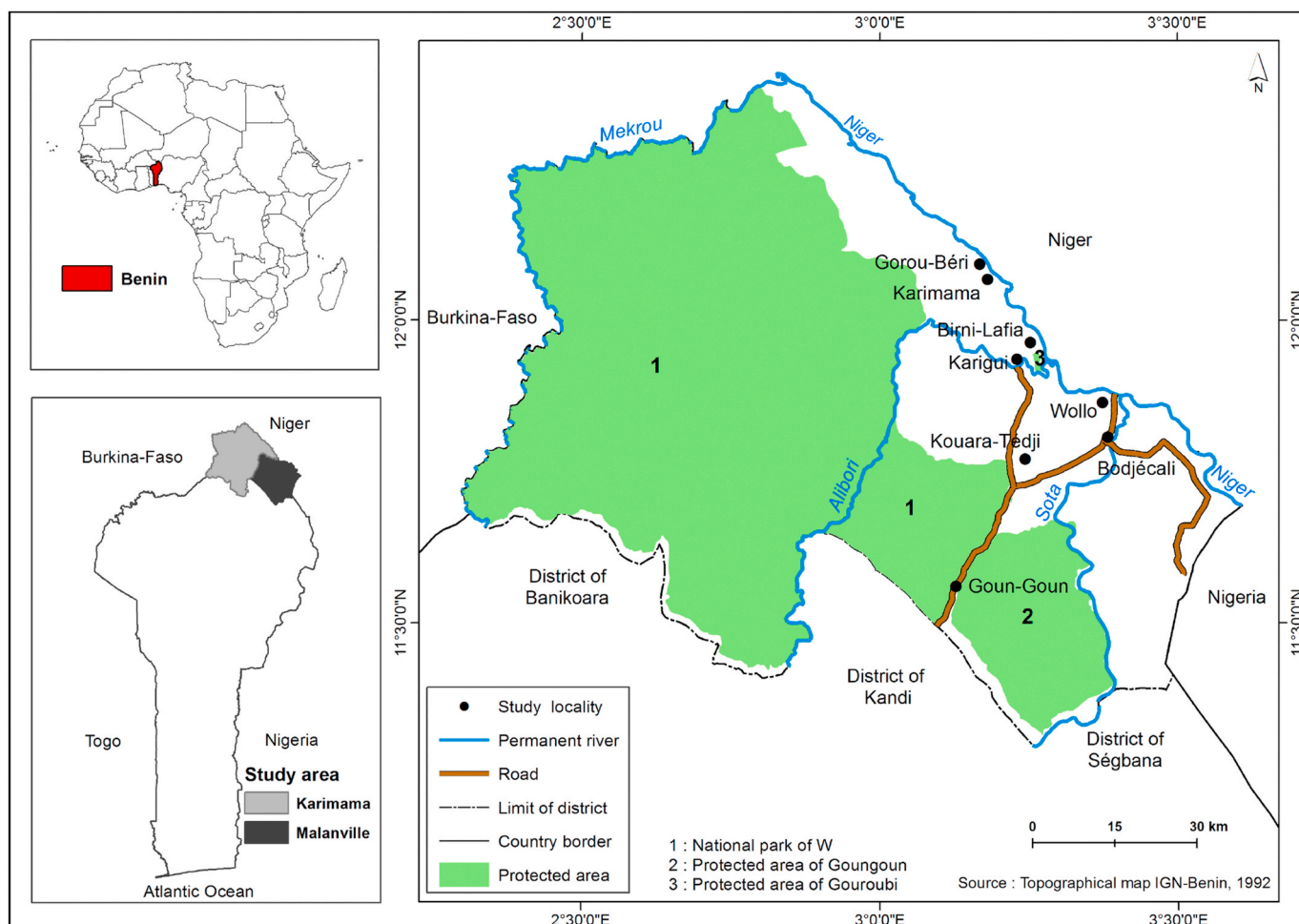


Fig. 1. Study area and villages visited. Source: Topographical Map IGN-Bénin.

equal weight method, because of its simplicity for application and ability to treat all indicators in the same (Wang and Fu, 2019), is applied during the first stage of aggregation where the normalised indicators are combined into components (social, human, natural, physical and financial capital) of adaptive capacity. At this stage, it was assumed that each indicator has the same importance in defining the component that they explained. However, this implied that indicators that have higher value have more impact on the value of the component compared to indicators with lower value. At the second stage, to combine components into a final composite index, expert judgement is used to define weighting schemes through focus group discussions. Since components of adaptive capacity are related to livelihood, weights will be easier to assign by local expert (Below et al., 2012) and allows the involvement of farmers in the assessment process. Community leaders who are farmers were used as experts to define weights. Farmers' perceived importance of adaptive capacity's components in their adaptation process were used as weights for each component. The importance of each component was elicited through focus groups discussion with community leaders in the study area (Malanville and Karimama).

2.2.3. Aggregation methods

A combination of both simple additive and weighted product methods were adopted to combine indicators into adaptive capacity index. This choice is made to take advantage of the properties of each method. The simple additive method of aggregation was used to combine indicators into indices that represent components of farmers' adaptive capacity (social, human, natural, physical and financial capital).

Let  $SC_{ij}$  be the index that captures farmer's  $i$  adaptive capacity component  $j$ .  $SC_{ij}$  are obtained from equation (2) which is a simple mean of the normalised measured ( $r_{ijk}$ ) of  $n$  indicators that define the component  $j$ .

$$SC_{ij} = \frac{1}{n} \sum_{k=1}^n r_{ijk} \tag{2}$$

After the indices that define adaptive capacity's components been computed, farmers' adaptive capacity was calculated using the weighted product method because it takes into account the complementarity among components, penalises components with poor values and is the best among the multiple attributes decision making (MADM) methods since it has the minimum loss of information (Zhou et al., 2010, 2006). Equation (3) indicates how adaptive capacity index ( $AC_i$ ) of a farmer  $i$  is obtained with the weighted product method where  $w_j$  the weight assigned to component  $j$  and  $t$  the number of components that defined adaptive capacity.

$$AC_i = \prod_{j=1}^t (SC_{ij})^{w_j} \tag{3}$$

The index scores obtained are comprised between 0 and 1. Present directly, the scores obtained for the index may limit its efficacy of the index to communicate with policy makers (Juhola and Kruse, 2013). The

**Table 2**  
Numbers of farmers interviewed per village.

Municipalities	districts	villages	Sample size
Malanville	Malanville	Wollo	57
		Bodjécali	67
		Guéné	67
Karimama	Karimama	Koara-Tédji	66
		Goungoun	47
		Karimama	46
		Gouroubéri	50
	Birni-Lafia	Birni-Lafia	50
		Karigui	50
Total			450

Source: Authors

solution proposed in the literature to overcome this limitation is the characterisation of the index to present results in visual form to highlight distribution and heterogeneity among farmers (Gupta et al., 2010; Juhola and Kruse, 2013). This approach was adopted and the commonly use method that transforms quantitative scores into qualitative values by dividing the range of scores into three groups with equal interval was applied. Following Asante et al.(2012), farmers' estimated adaptive capacity  $AC_i$  was characterised into three (03) groups. A farmer is considered having low capacity if  $0 < AC_i < 0.33$ , moderate capacity if  $0.33 < AC_i < 0.66$  and high capacity if  $0.66 < AC_i \leq 1$ .

2.2.4. Uncertainty analysis

An uncertainty analysis was performed on the adaptive capacity indices to find out whether the use of mixed weighting scheme is subject to less uncertainty compared to the common case where the equal weighting scheme is applied. The relative standard deviation (RSD) was used as indicator of uncertainty. In order to analyse the consistency of the uncertainty, a Monte Carlo simulation was performed to appreciate the value of RSD related to the adaptive capacity index from 10000 samples.

2.3. Data

The study is carried out in the northern part of Benin, in Alibori region because it is the most productive in food crop production and is also exposed to climate change events (Vodounou and Doubogan, 2016; Yabi and Afouda, 2012; MAEP, 2011). A multi-stage sampling technique was used to select smallholder farmers. At the first stage, two municipalities were selected within Alibori. The vulnerability to weather risks criteria was used at this stage and then Malanville and Karimama municipalities were selected because they are the most vulnerable to climate change (MEPN, 2007). At the second stage, two districts were selected within each municipality based on density of agricultural population and the same criteria were used to select two villages within each district at the third stage. Lists of farmers per village were obtained from extension offices at Malanville and Karimama and random selection of farmers was performed. Fig. 1 shows the location of Alibori region on Benin's map, Karimama and Malanville districts and locations of villages where data were collected.

The minimum required sample size for the study was obtained using equation (4) and proportionality sampling technique is used to determine the number of smallholder farmers to interview in each village.

**Table 3**  
Socioeconomic characteristic of respondents.

Variables	All	Malanville	Karimama	T-test or Chi2
Sex				
Man	0.91	0.87	0.96	-3.38***
Age	48.63	48.39	48.95	-0.83
Education				
Not educated	0.60	0.57	0.63	2.21
Primary	0.30	0.33	0.26	
Secondary	0.10	0.10	0.11	
Experience in Agriculture	24.75	25.95	23.13	3.16***
Main Crop				
Maize	0.29	0.33	0.23	9.69**
Rice	0.32	0.32	0.31	
Millet	0.20	0.16	0.26	
Sorghum	0.19	0.19	0.20	
Farm size	2.4	2.7	2.05	5.53***
FBO	0.67	0.68	0.66	0.48
Extension services	0.75	0.77	0.72	1.29
Access to credit	0.62	0.60	0.65	-0.99
Perception of climate change	0.90	0.87	0.92	-1.75*
Experience with natural hazard event	0.31	0.30	0.33	-0.81

Source: Authors' Field work (2016)

**Table 4**  
Component of farmers' adaptive capacity to climate change.

Component of Adaptive capacity	All sample		Karimama		Malanville		Prob(t-test)
	Mean	Std dev	Mean	Std dev	Mean	Std dev	
Social capital	0.30	0.13	0.33	0.13	0.28	0.13	0.000***
Human capital	0.24	0.09	0.25	0.09	0.24	0.09	0.383
Natural capital	0.38	0.08	0.36	0.09	0.40	0.07	0.000***
Physical capital	0.20	0.08	0.24	0.09	0.17	0.05	0.000***
Financial capital	0.27	0.11	0.28	0.11	0.28	0.11	0.893

Source: Authors' Field work (2016)

**Table 5**  
Weighting scheme used to compute adaptive capacity index.

Adaptive capacity component	Malanville		Karimama	
	rank	weight	rank	weight
Social capital	2	0.2	1	0.3
Human capital	3	0.2	3	0.2
Physical capital	4	0.2	4	0.2
Natural capital	5	0.1	5	0.1
Financial capital	1	0.3	2	0.2

Source: Authors' Field work (2016)

$$n = \frac{t^2 p(1-p)}{E^2} \tag{4}$$

Where t represents the t-value corresponding to the level of confidence (α) chosen by the researcher, P the proportion of population having attributes of interest and E the margin of error. Since agriculture is the main source of income and employs 70% of labour force in Benin (INSAE, 2012), it is assumed that 70% of population in Alibori region Benin are engaged in agriculture, thus P = 0.70 and a 5% (E = 5%) margin error was adopted. The minimum required sample size was 323 farmers. Because of non-responses to some questions which will lead to missing data and reduce the sample size for analysis, the sample size was over-estimated to be able to meet the minimum sample size requirement after data cleaning. A total of 450 smallholder farmers were randomly selected and interviewed with structured questionnaire. Table 2 shows the repartition of farmers interviewed per villages.

2.3.1. Focus group discussion

One focus group discussion with community leaders was carry out in each community. The group of community leaders was composed by chef of village visited in a community assisted by 3 or 4 notables that are well known and are involved in agricultural production. They were in total 8 leaders that participated in the discussion for Malanville compared to 7 leaders for Karimama. Two main activities were executed during the discussion. For the first activity farmers were asked, after the meaning of the concept being explained to them, to rank the five capitals, social, natural, physical, human and financial, respect to their contribution to build adaptive capacity from their experience. The ranking was performed from one, most important to five, the least

**Table 6**  
Farmers' adaptive capacity to climate change index.

	Weighted product method			Simple Additive method		
	Mixed weights	Equal weights	Difference	Mixed weights	Equal weights	Difference
All sample	0.255 (26)	0.261 (23)	-0.006***	0.274 (24)	0.282 (21)	-0.008***
Karimama	0.275 (25)	0.277 (23)	-0.002**	0.291 (24)	0.294 (21)	-0.003***
Malanville	0.241 (25)	0.250 (22)	-0.008***	0.261 (22)	0.273 (20)	-0.011***

\*\*\*p < 0.01, \*\*p < 0.05. Value in parentheses are the relative standard deviation (RSD).

Source: Authors' Field work (2016)

important component. For the second activity, the budget allocation technique is applied and ten stones were giving to farmers to share on the components of adaptive capacity respect to their contribution to adaptation process from their experience. More stones on a component means that component is important in the adaptation process in the area and must have higher weight. The same number of stones on component reveal that components of adaptive capacity have the same importance in adaptation process and then deserve the same weight. The weight of each component is obtained by dividing the number of stone put on the component by the total stones given.

3. Results

3.1. Socioeconomic characteristics of respondents

Table 3 summarizes socio-economic characteristics of farmers interviewed. It shows that man are more involved in crop production than woman in the study area and this is observed in the two communities. Farmers' population is dominated by non-educated persons and they have on average twenty four years of experience in agriculture with farmers in Malanville more experienced than farmers in Karimama. Maize and rice are the most grown crop by cereal farmers in Malanville compared to rice and millet for farmers in Karimama. Majority of farmers interviewed have access to institutional support such as extension service and credit (either formal or informal) for agricultural production and are also member of farmers based organization (FBO). Climate change is observed in the study area by majority of farmers in term of increase in temperature, decrease of annual rainfall and late onset of rains. However only 31% of farmers experienced natural events such as flood and drought on their farms in the last five years.

3.2. Components of adaptive capacity to climate change

Assessment of indices that captured components of smallholder farmers' adaptive capacity are summarised in Table 4. It shows that farmers adaptive capacity to weather risk in the study area are built with

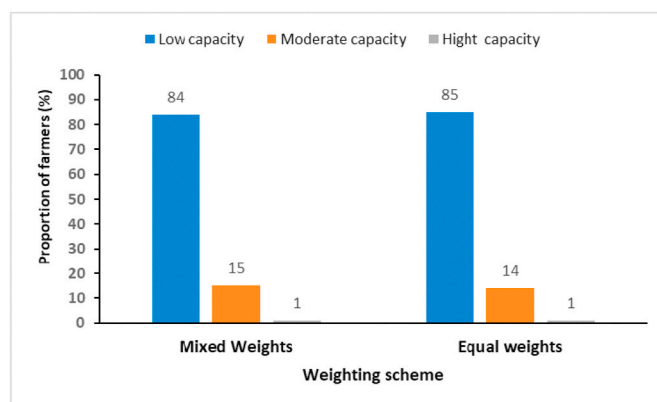


Fig. 2. Characterisation of farmers' adaptive capacity based on weighted product index. Source: Authors' Field work (2016).

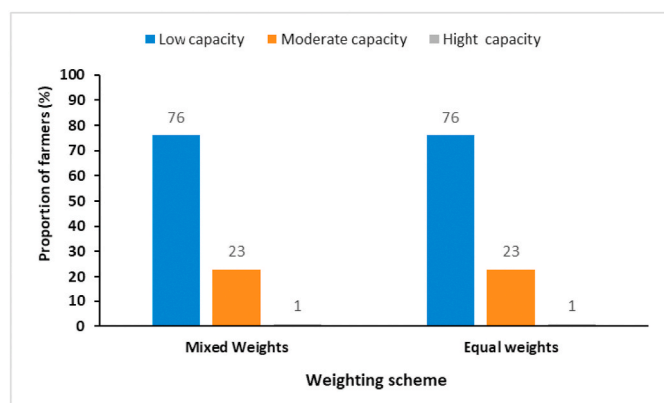


Fig. 3. Characterisation of farmers’ adaptive capacity based on simple additive index. Source: Authors’ Field work (2016).

a low level of social, human, physical and financial capital and moderate level for nature capital. However, there is disparity between the two municipalities for some components of adaptive capacity. Farmers in Karimama municipality appear to have a relatively higher social, nature, and physical capital compared to farmers in Malanville municipality and the differences are statistically significant.

3.3. Weighting scheme proposed by smallholder farmers for adaptive capacity components

The results of focus groups discussion with leaders in the two communities are presented in Table 5. Community leaders in both Malanville and Karimama, ranked social and financial capital as important components to build adaptive capacity to climate change whilst natural capital is considered the least important component. The same results were also observed during the budget allocation exercise. However, leaders in Karimama indicate social capital as the most important capital to build adaptive capacity within the adaptation process compared to leaders in Malanville who point out financial capital. From farmers’ perspective in both communities, although financial resources are crucial to respond to weather risks, collective action, support from friends and relatives and networking are also important to avoid or overcome the negative impact of weather risks events. The main reason pointed out by community leaders during the discussion was that “when an individual pass through a difficult moment due to weather risks, reliefs from friends and family boost their morale to surmount the problem psychologically before financial resources play their roles”. These results are consistent with others studies who demonstrate that financials capital (Monterroso et al., 2018), relationship and network (Keys et al., 2016) are keys factors to build adaptive capacity to climate change. The results provide also empirical support to the view that social factors are important as financial factors to build farmer’s adaptive capacity to climate change (Clay and King, 2019; Hogan et al., 2011; Williges et al., 2017).

These results show a similarity between the ranking and weighting proposed by leader un both communities and suggest leaders have the same view of adaptive in two communities, but they do not attribute the

Table 7 Adaptive capacity scores and associated RSD from Monte Carlo simulation.

	Weighted product method			Simple additive method		
	Mixed weights	Equal weights	Difference	Mixed weights	Equal weights	Difference
Indices	0.24	0.25	-0.01***	0.41	0.27	0.14***
RSD (%)	22	20	0.02***	46	16	30***
Number of simulations	10000					

\*\*\*p < 0.01, \*\*p < 0.05.

Source: Authors’ Field work (2016)

same importance to the five capitals (social, financial, human, natural and physical) to build their adaptive capacity and how they affect the adaptation process. However, there is inconsistency between the ranking and the weights proposed by leaders in both communities through the budget allocation exercise. Component that were ranked at second, third and fourth for their importance in building adaptive capacity received the same (number of stones) weight for their contribution to adaptation process. Despite that, the weights proposed by leaders during the budget allocation exercise were used to compute the composite index of adaptive capacity since they reflect the contribution of adaptive capacity components to adaptation process.

3.4. Smallholder farmers’ adaptive capacity to weather risk

Regardless of the methods and the weighting schemes used to compute adaptive capacity indices, the results show that, on average smallholder farmers have low adaptive capacity to weather risks in the study area (Table 6). This result is consistent with the claim that majority of smallholders farmers in developing country have low adaptive capacity as shown by previous studies (Egyir et al., 2015; Mekonnen and Kassa, 2019; Shirima et al., 2017). Results also show that, there is a small difference between the average values of indices estimated with mixed weighting scheme compared to the average value of indices estimated with equal weighting schemes respect to methods used to compute the indices. This could suggest that, respect to the method use, mixed weights and equal weights leads to the same results.

However, the differences in the average value of indices for each case are statistically different to zero and the relative standard deviation obtained for indices computed with mixed weights scheme are slightly higher than those obtained for indices computed with equal weights scheme. These results suggest that there is more uncertainty related to indices computed with mixed weights scheme compared to indices computed with the equal weights scheme.

The characterisation of the indices (Figs. 2 and 3) shows that, respect to the methods used to compute the index (weighted product or simple additive), mixed weighting and equal weighting schemes lead to the same results. In fact, with the weighted product method, both mixed weights and equals weights indices indicate that majority of smallholder farmers (84%) in the study area have low adaptive capacity to weather risk while with the simple additive method both methods weighting scheme show that 76% of smallholder farmers that low adaptive capacity.

3.5. Uncertainty analysis on adaptive capacity indices

The results of uncertainty analysis using Monte Carlo simulation are summarised in Table 7. It shows that over 10000 simulations, smallholder farmers have low adaptive capacity in the study area. The averages values of adaptive capacity indices obtained with mixed weights and equals weights are closed when the indices are computed with the weighted product method although the difference is statistically significant. Similar pattern is observed for uncertainties (RSD) related to the indices. When adaptive capacity indices are computed with simple additive method, simulation shows that there is large difference between the average value of mixed weights index and the average value of equal

weighted index and the same pattern is observed between uncertainties related to each index. The results suggest that the mixed weighting scheme performed better when applied on the weighted product aggregation method and produced almost the same results as the equal weights.

#### 4. Discussion

The assessment shows that smallholder farmers do not attribute the same importance to the five capital of sustainable livelihood framework to build their adaptive capacity and that change from one community to another. These results suggest that weighting scheme should be specific to each community and are consistent with other studies who found that communities of farmers are heterogeneous groups (Hogan et al., 2011; Smit and Wandel, 2006) and one-size-fits-all weighting scheme (equal weights) methods are inappropriate to reflect the socio-economic and environmental conditions under which farmers mediate their livelihood decision (Hinkel, 2011) and the trade-offs among components.

The analysis shows that mixed and equals weighting schemes leads to similar results when the composite indices is computed with weighted product methods. However, they have different results when simple additive aggregation method is used to compute the composite indices. These results indicate how important are the choice of weighting scheme and aggregation methods in index construction and are consistent with those obtained by Marzi et al. (2018), who show that adaptive capacity index score is sensitive to the aggregation and weighting methods. Results also suggest that weighted product method is the most appropriate aggregation method when the mixed weighting scheme is adopted.

Both indices lead to the conclusion that smallholder farmers in both communities, Karimama and Malanville, have in majority low adaptive capacity. With equal weights index, policy makers may not know which components to prioritise for policy interventions or apply the same strategy for both communities since most of the component indices suggest low level of capital. This could be misleading since the two municipalities are not homogenous groups. With mixed weights index, interventions that create incentive for social capital improvement could be applied in Karimama while interventions to improve farmers' access to financial capital could be implemented in Malanville since farmers reveal those capitals as most important components for their adaptive capacity. These additional information provides by the mixed weighting scheme index were obtained thought the weights definition process which make that index more relevant for policy formulation compared to the index computed with equal weighting scheme.

This suggests that improvement in methods used to define weights of composite index to evaluate adaptive capacity can help have addition information useful for policy implementation while maintaining the same level of information provided by the final results. The combination of weights definition methods throughout the index development the process can help define mixed weighting scheme that will provide additional information for policy formulation if weighted product aggregation method is used. Though, several combinations could be defined, association of expert judgment methods with others methods should be prioritised since it can provide venues to take into account the perceived importance of indicators and component.

#### 5. Conclusion

The need to quantify adaptive capacity to climate change at various levels, to help define vulnerability and inform policy makers, has led scholars to use composite indices which requires the use of weighting scheme for aggregation. Various methods (equal weights, data driven weights and experts' judgement) have been proposed to define weighting scheme for adaptive capacity assessment. However, those weights definitions methods when applied at household or individual level to assess adaptive capacity to climate change provide weighting scheme that do not reflect perceived importance of components to the

unit of analysis and then fail to provide relevant policy information except the level of adaptive capacity that will be provided. This study assesses smallholder farmer's adaptive capacity to climate change by using a mixed weighting scheme. The mixed weighting scheme is defined through the combination of equal weights and expert judgment methods to define a weighing scheme that reflect farmers' perceived importance of each components of their adaptive capacity since farmers were used as experts. The results show that the mixed weighing scheme adaptive capacity index lead to the same characterisation as the equal weighting scheme index when weighted product aggregation method is used to combine components. This provides empirical support to the growing demand to integrate the quantitative assessment framework with elements of the qualitative approach such stakeholder interactions and use of experts. However, the results should be taken with caution since the framework used for the analysis focus mostly on socio-economic factors compared to environmental factors which also define adaptive capacity. Moreover, the selection and the number experts used during the focus group and the method used to elicit leaders perceived importance of adaptive capacity may influence the quality of information provided. The definition of an assessment framework that can provide the appropriate method of selection of experts and their number with the way in which their opinions will be taken into account, without increase uncertainty related to the indices, would advance knowledge on integrated methods of adaptive capacity assessment. Though, there is more uncertainty related to the mixed weighting method, it should be prioritised for weights definition when adaptive capacity is assessed at individual level with indicators approach.

#### CRedit authorship contribution statement

**Yves C. Zanmassou:** Conceptualization, Methodology, Formal analysis, Writing - original draft. **Ramatu M. Al-Hassan:** Writing - review & editing, Investigation, Visualization, Supervision. **Akwasi Mensah-Bonsu:** Writing - review & editing. **Yaw B. Osei-Asare:** Writing - review & editing. **Charlemagne B. Igue:** Investigation, Supervision.

#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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#### Appendix A. Supplementary data

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