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CACCI
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CACCI FIELD NOTES

Vulnerability to Climate Change in Senegal

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About the CACCI Field Notes

AKADEMIYA2063 CACCI Field Notes are publications by AKADEMIYA2063 scientists and collaborators based on research conducted under the Comprehensive Action for Climate Change Initiative (CACCI) project. CACCI strives to help accelerate the implementation of Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs) by meeting the needs for data and analytics and supporting institutional and coordination capacities. In Africa, CACCI works closely with the African Union Commission, AKADEMIYA2063, the African Network of Agricultural Policy Research Institutes (ANAPRI), and climate stakeholders in selected countries to inform climate planning and strengthen capacities for evidence-based policymaking to advance progress toward climate goals.

Published on the AKADEMIYA2063 website (open access), CACCI Field Notes provide broad and timely access to significant insights and evidence from our ongoing research activities in the areas of climate adaptation and mitigation. The data made available through this publication series will provide evidence-based insights to practitioners and policymakers driving climate action in countries where the CACCI project is being implemented.

AKADEMIYA2063's work under the CACCI project contributes to the provision of technical expertise to strengthen national, regional, and continental capacity for the implementation of NDCs and NAPs.

AKADEMIYA2063 is committed to supporting African countries in their efforts against climate change through provision of data and analytics using the latest available technologies. In this Field Note, AKADEMIYA2063 scientists provide household vulnerability assessments to support the design and implementation of ongoing climate adaptation actions in Senegal.

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About AKADEMIYA2063

AKADEMIYA2063 is a pan-African non-profit research organization with headquarters in Kigali, Rwanda and a regional office in Dakar, Senegal. Inspired by the ambitions of the African Union's Agenda 2063 and grounded in the recognition of the central importance of strong knowledge and evidence-based systems, the vision of AKADEMIYA2063 is an Africa with the expertise we need for the Africa we want. This expertise must be responsive to the continent's needs for data and analysis to ensure high-quality policy design and execution. Inclusive, evidence-informed policymaking is key to meeting the continent's development aspirations, creating wealth, and improving livelihoods.

AKADEMIYA2063's overall mission is to create, across Africa and led from its headquarters in Rwanda, state-of-the-art technical capacities to support the efforts by the Member States of the African Union to achieve the key goals of Agenda 2063 of transforming national economies to boost economic growth and prosperity.

Following from its vision and mission, the main goal of AKADEMIYA2063 is to help meet Africa's needs at the continental, regional and national levels in terms of data, analytics, and mutual learning for the effective implementation of Agenda 2063 and the realization of its outcomes by a critical mass of countries. AKADEMIYA2063 strives to meet its goals through programs organized under five strategic areas—policy innovation, knowledge systems, capacity creation and deployment, operational support, and data management, digital products, and technology—as well as innovative partnerships and outreach activities. **For more information**, visit www.akademiya2063.org.

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1. Introduction

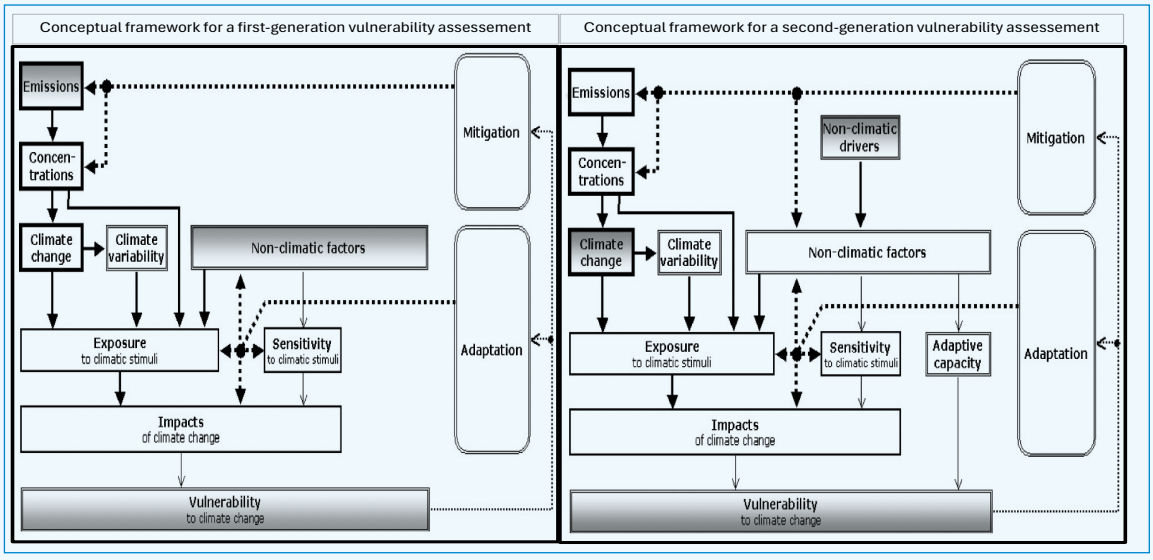
Since 2015, Senegal has been engaged in the process of developing its National Adaptation Plan (NAP). In this context, assessing household vulnerability to climate change is an important step to identify medium- and long-term adaptation options. The aim of this brief is to provide household vulnerability assessments to support the design and implementation of ongoing climate adaptation actions. To this end, we have followed the Intergovernmental Panel on Climate Change (IPCC) framework to estimate the composite Vulnerability to Climate Change (VCC) Index. In the following sections, we will first recall the conceptual framework for vulnerability assessment, then present methods of estimating vulnerability before finally presenting the results of the assessment of household vulnerability in the different regions of Senegal.

2. Conceptual framework for vulnerability assessment

Climate impact assessments evaluate the potential effects of one or several climate change scenarios on one or more impact domains and compare them to a constant climate. A climate vulnerability assessment is an extension of a climate impact assessment. We distinguish between two generations of climate vulnerability assessments. The step from climate impact assessment to first-generation vulnerability assessment is characterized primarily by the evaluation of climate impacts in terms of their relevance for society and by the consideration of potential adaptation. The main novelty of second-generation vulnerability assessments is the more thorough assessment of the adaptive capacity of people, thus shifting the focus from potential to feasible adaptation. Therefore, the second generation of climate vulnerability assessments emphasize vulnerability with three components: exposure, sensitivity and adaptation capacity.

The exposure of a system to climate refers to the magnitude of climatic variations that the system is expected to face. It therefore depends on the level of global climate change and, due to the spatial heterogeneity of anthropogenic climate change, on the system's location. Burton (1997) suggests a hierarchy of weather and climate phenomena (denoted as type 1, 2, and 3 variables) to distinguish between single climate variables (such as local temperature), specific weather events (such as a convective storm), and long-term processes (such as anthropogenic climate change). The inclusion of any of these aspects in the exposure definition of a particular vulnerability assessment depends on the specific circumstances. The sensitivity of a system refers to the degree to which a system may be affected by exposure to climate change risks. This therefore denotes the (generally multi-factorial and dynamic) dose–response relationship between its exposure to climatic stimuli and the resulting impacts. Adaptive capacity refers to the ability of a system to adjust to climate change. Brooks (2003) classifies factors that determine adaptive capacity into hazard-specific and generic factors, and into endogenous and exogenous factors. Generic determinants of adaptive capacity in social systems comprise such non-climatic factors as economic resources, technology, information and skills, infrastructure, institutions, and equity (Smit and Pilifosova 2001; Yohe and Tol 2002). Endogenous factors refer to the characteristics and behavior of the considered population group whereas exogenous factors include the wider economic and geopolitical context.

Figure 1: Pathway for vulnerability assessment



Source: Authors' compilation from Hans-Martin Füssel

3. Methods of estimating households' vulnerability to climate change

Estimation of the composite household vulnerability indicator is guided by the conceptual framework of climate-related risks contained in the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) Working Group exploring the potential impacts of climate change on agriculture and food security (Adger 2006; O'Brien et al. 2007; Ravindranath and Sharma 2019). The IPCC defines vulnerability as "the extent to which a natural or social system is likely to be damaged by the impacts of climate change, and is a function of exposure, sensitivity and adaptive capacity" (IPCC 2014). In line with this definition, household vulnerability in each administration level is estimated by calculating the administration level score 'i' for each of the three dimensions (exposure, sensitivity, and adaptation capacity). Subsequently, these dimension scores are summed up to obtain the overall Vulnerability to Climate Change (VCC) Index. The results obtained support the comparison and assessment of household vulnerability to climate change for each administration level. Formula:

$$\boldsymbol{VCC_i = \frac{1}{3}(Exposure\ score_i + Sensitivity\ score_i - Adaptation\ capacity\ score_i)}$$

With:

$$\begin{cases} \text{Exposure score}_i = \dfrac{1}{n_E}\displaystyle\sum_{k=1}^{n_E} V_{k,i}^{\text{Exposure}} \\ \text{Sensitivity score}_i = \dfrac{1}{n_S}\displaystyle\sum_{k=1}^{n_S} V_{k,i}^{\text{Sensitivity}} \\ \text{Adaptation capacity score}_i = \dfrac{1}{n_{IA}}\displaystyle\sum_{k=1}^{n_{IA}} V_{k,i}^{\text{Adaptation capacity}} \end{cases}$$

index $\boldsymbol{i}$ *represents* administration level; $\boldsymbol{n_E, n_S, n_{IA}}$ *correspond to the number of select variables for each dimension*

$\boldsymbol{V_{k,i}^{Exposure}}$ *correspond to the* $\boldsymbol{k^{th}}$ *normalized variable of the region* $\boldsymbol{i}$ *for exposure dimension*

In addition to estimating the composite indicator, we analyze the vulnerability level of each administration level according to two types of categorizations. The first categorization is called 'relative' and helps to compare and prioritize the districts of the country and to identify those among the administration level that are 'Much more vulnerable', 'More vulnerable', 'Less vulnerable' and 'Much less vulnerable'. The second categorization is called 'absolute' insofar as it helps to compare the state of VCC across countries or over the years.

Figure 2: Categorization of vulnerability

Relative categorization:k-means approach

The k-means clustering algorithm is a technique used for partitioning a dataset into a predetermined number of clusters. Here's an overview of the k-means method:

-Randomly select k initial cluster centroids (points in the feature space). These centroids represent the initial cluster centers.
-Assign each data point to the nearest cluster centroid based on a distance metric, commonly the Euclidean distance. Each data point is assigned to the cluster whose centroid is closest to it.
-Recalculate the cluster centroids by taking the mean of all data points assigned to each cluster. This moves the centroids to the center of their respective clusters.
-Iterate steps 2 and 3 until convergence is reached, typically when the cluster assignments no longer change or when a specified number of iterations is reached.
-Once convergence is achieved, the final clustering is obtained. Each data point belongs to the cluster associated with the nearest centroid.

As results, we will obtain the four following clusters:

Absolute categorization:

Absolute classification is a method that involves categorizing data points into predefined classes or categories based on specific criteria. Here's how the absolute classification method typically works:

-First, you need to define the classes or categories into which you want to classify your data. These classes should be mutually exclusive and exhaustive, meaning that every data point must belong to one and only one class.
-Determine the criteria or rules for assigning data points to each class. These criteria could be based on specific thresholds, ranges, or conditions related to the attributes or features of the data.
-Apply the established criteria to assign each data point to the appropriate class. This assignment is typically binary, where a data point either meets the criteria for inclusion in a class or does not.
-Evaluate the effectiveness of the classification method by assessing how well it categorizes the data according to the defined criteria.

As results, we will obtain the four following classes:

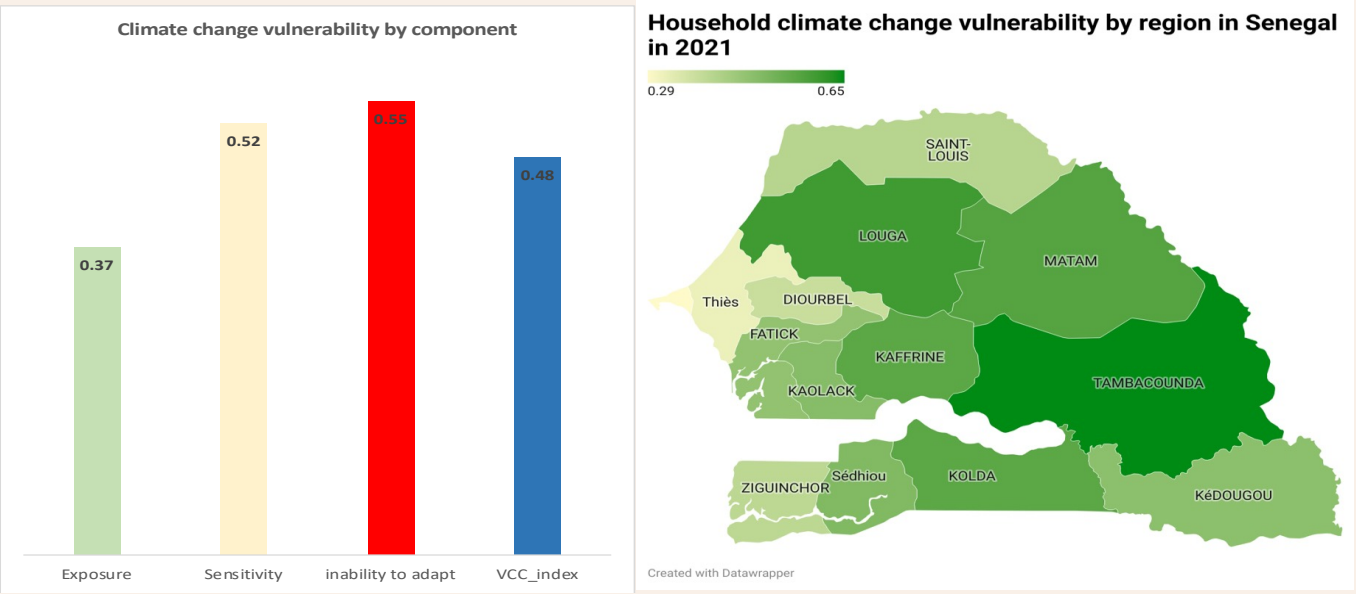
Source: Authors' compilations

4. Vulnerability assessment results

For the case of Senegal, the Vulnerability to Climate Change (VCC) index results shown in Figure 3 reveal that the overall level of household vulnerability in Senegal is 0.48 on a scale of 0 to 1 (the closer the value is to 1, the higher the vulnerability). The composite VCC index is explained more by the inability of households to adapt (score = 0.57) followed by their sensitivity to climate change (score = 0.49) and finally the level of exposure of households with a fairly low score (0.37). The result indicates that though the level of exposure is somewhat low, households in Senegal are very sensitive to any climate risk exposure and have very limited capacity to adapt to the adverse effects. Looking at Figure 3, we note that the Tambacounda region stands out as being the region most vulnerable to climate change. Indeed, it records the highest level of vulnerability with a score of 0.65. This region is followed by Louga Matam, Kolda, Kaffrine and Sédhiou, which have recorded scores above 0.5. The two regions with the least vulnerable households are Dakar (score=0.29) and Thiès (score=0.32), indicating that households in urban areas are

less vulnerable to climate change as they have options for income diversification, and better access to markets and public services. The other regions have a medium level of vulnerability with scores ranging between 0.38 and 0.49. Beyond these results, we show how each of the three dimensions of vulnerability evolves simultaneously in each region.

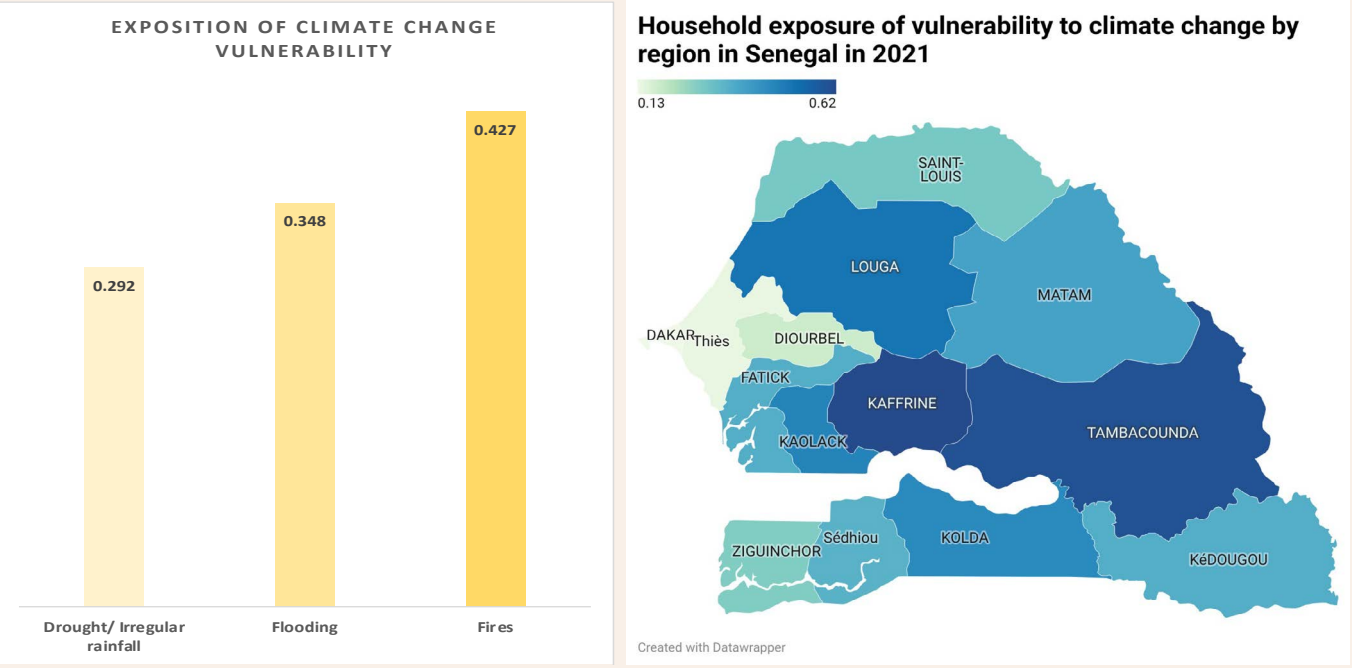
Figure 3: Senegal's household vulnerability to climate change in 2021



Source: Authors' calculations using data from EHCVM and DAPSA

In view of the results, we note that households residing in the regions of Tambacounda, Kaffrine and Louga are very exposed to climate change because they have scores above 0.5. Households in the regions of Dakar, Thiès, Diourbel, Ziguinchor and to a lesser extent Saint Louis are the least exposed to climate change with scores under 0.3. Households residing in other regions of Senegal are moderately exposed to climate change. The computation of the exposure dimension was based on four variables: precipitation, drought/irregular rainfall, flooding and fires. At the national level, the results show that heavy rainfall and the frequency and intensity of fires are the variables that most explain the exposure of households to climate change compared to flooding and drought/irregular rainfall variables.

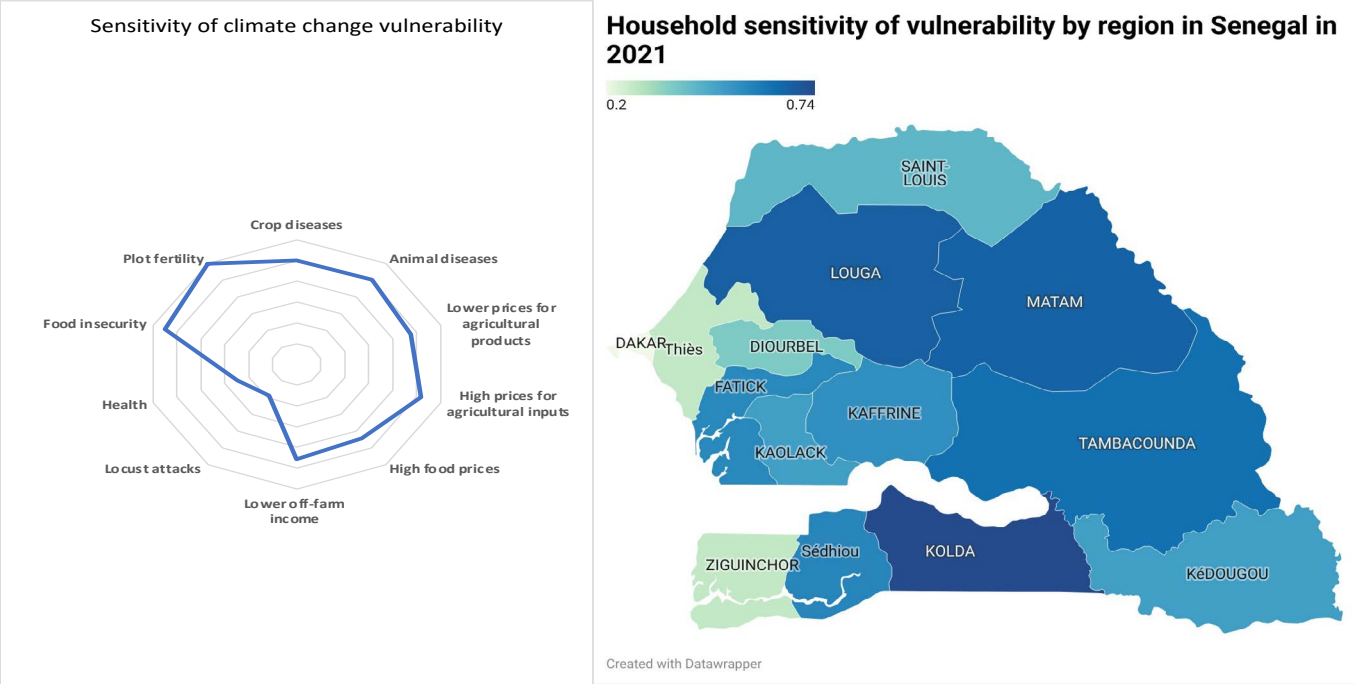
Figure 4: Senegal's household exposure to climate change in 2021



Source: Authors' calculations using data from EHCVM and DAPSA

The results of the sensitivity dimension presented in Figure 5 reveal that households in the Kolda region are the most sensitive to climate change risks with a score of 0.74. Households in Louga (0.68), Matam (0.67) and Tambacounda (0.63) are also very sensitive to climate change. In the regions of Sédhiou, Fatick and Kaffrine, scores vary between 0.54 and 0.057, also reflecting the sensitivity of their households. In terms of household sensitivity, the lowest scores are found in Dakar, Thiès, Ziguinchor and to a lesser extent in Diourbel. The sensitivity of households to climate change is mainly associated with low levels of irrigated cultivation by farmers. Added to this are the infertility of cultivated areas, a high demographic dependency rate, food insecurity, high prices for agricultural inputs, animal diseases, and crop diseases.

Figure 5: Senegal's household sensitivity to climate change in 2021

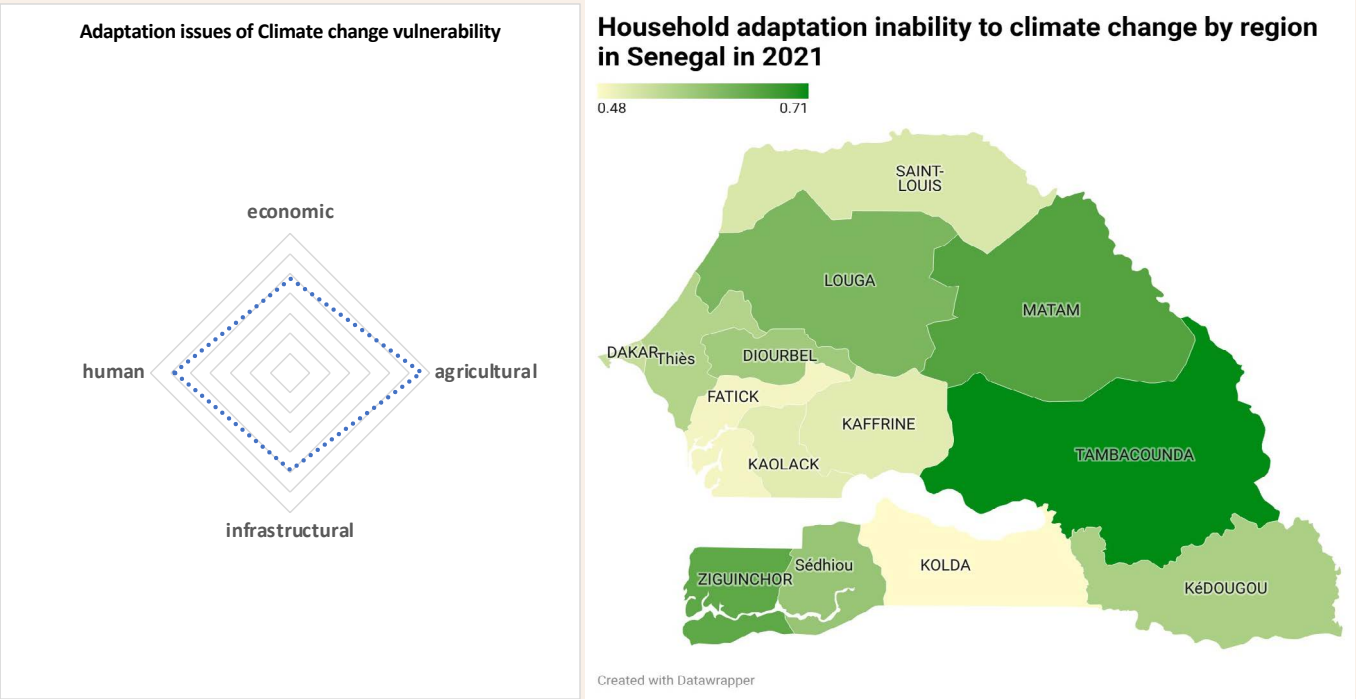


Source: Authors' calculations using data from EHCVM and DAPSA

Following this line of argument, the results reveal that households residing in the region of Tambacounda have the lowest capacity or the highest incapacity score for adaptation to climate change (with a score of 0.71). This interpretation remains valid for households in the region of Matam (score=0.66), Ziguinchor (score=0.65) and Louga (score=0.62). The regions of Kolda and Kaffrine score the lowest out of all the regions in this respect. This means that households in these two regions have more capacity to adapt to climate change than households in other regions of Senegal. With regard to the four sub-dimensions that we define to calculate the score of this dimension, low agricultural performance (score=0.66) and limited human capital (score=0.58) best explain the inability of households to adapt to climate change.

The highest score in agriculture is associated with the small proportion of households who make use of improved seed varieties, animal or household waste, inorganic fertilizer, and practice multiple cropping or have irrigated plots. The inability of households to adapt to climate change through the human capital subdimension is generally explained by a very low level of female entrepreneurship index, the proportion of household heads using agricultural information, households having processed agricultural products (%), and the proportion of women with access to agricultural land by region (%).

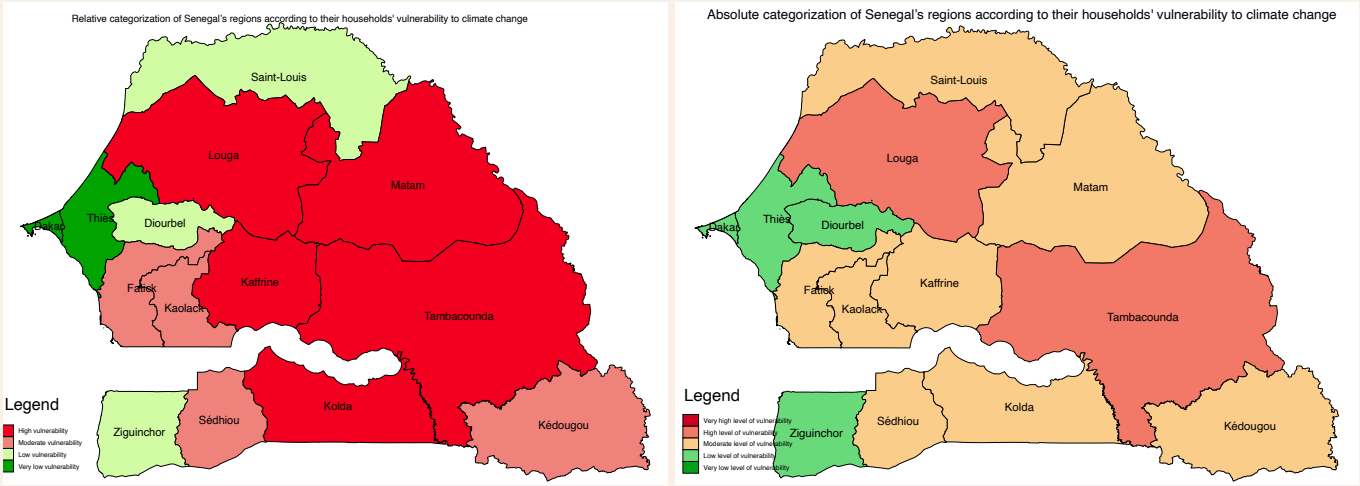
Figure 6: Senegal's household adaptation issues to climate change in 2021



Source: Authors' calculations using data from EHCVM and DAPSA

Figure 7 presents the results of the classification of the level of vulnerability between countries (absolute classification) and then between the regions of Senegal (relative classification). Figure 7 therefore reveals that in absolute terms there are no regions of Senegal where household vulnerability is very low. However, the central-western regions (Dakar, Thiès, Diourbel) and the south-west (Ziguinchor) are characterized by households with a low level of vulnerability. The northeastern regions are characterized by households with a moderate level of vulnerability. Households in the Tambacounda and Louga region have a high level of vulnerability. Here we describe the situation of household vulnerability in a relative way between the different regions of Senegal according to the following four classes: very low vulnerability, low vulnerability, moderate vulnerability and high vulnerability. Thus, the results reveal that households in Dakar and Thiès have a very low level of vulnerability while households in the regions of Louga, Matam, Tambacounda, Kaffrine and Kolda are very vulnerable.

Figure 7: Categorization of households' vulnerability in Senegal's regions in 2021



Source: Authors' calculations using data from EHCVM and DAPSA

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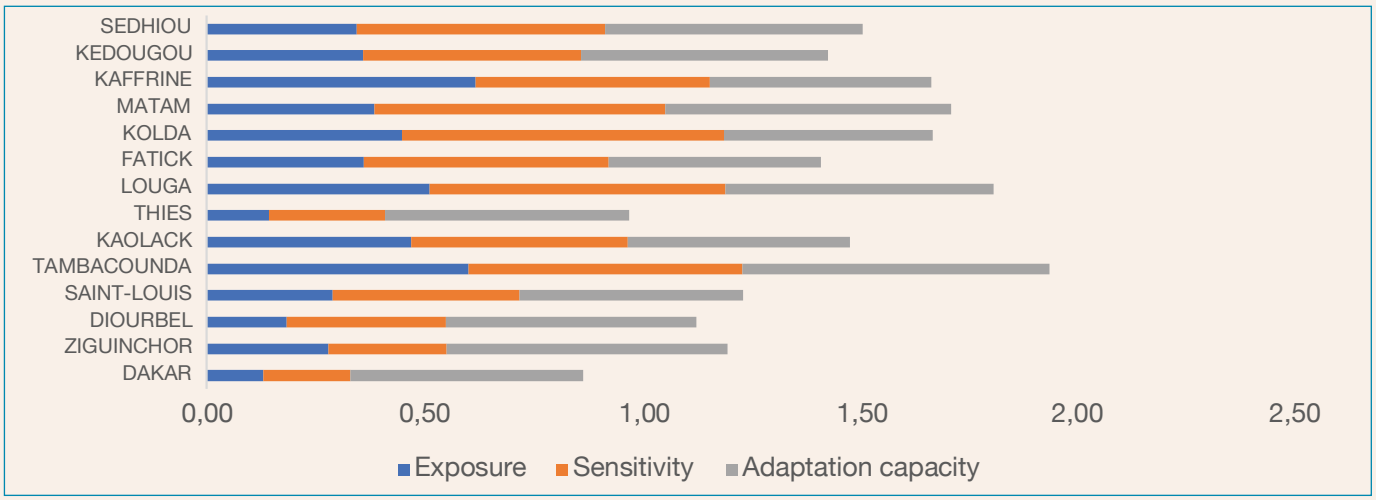
6. Annexes

Annex 1: Distribution of vulnerability to climate change by region



Source: Authors' calculations using EHCVM and DAPSA data

Annex 2: The indicators considered for constructing the exposure index.

Indicators	Correlation with VCC
Exposure to drought/ irregular rainfall	Positive
Exposure to flooding	Positive
Exposure to fires	Positive
Exposure to heavy rainfall	Positive

Source: Authors' calculations using EHCVM and DAPSA data

Annex 3: The indicators considered for constructing the sensitivity index.

Indicators	Correlation sens with VCC
% of household suffered high rate of crop disease	positive
% of household suffered high rate of animal diseases	positive
% of household suffered significant drop in prices of agricultural products	positive
% of household suffered high prices for agricultural inputs	positive
% of household suffered high food prices	positive
% of household suffered significant loss of off-farm income	positive
% of household suffered locust attacks or other crop pests	positive
% of households with at least one member that suffered skin problems	positive
% of households with at least one member that suffered eye disease	positive
% of households eating less than they should have	positive
% of households that skipped a meal through lack of money	positive
% of households that ate a poor variety of food	positive
% of households that couldn't eat healthy, nutritious food	positive
% of households worried about not being able to eat	positive
% of households with fertility plot (good-medium-low)	negative
Shocked households (%)	positive
Demographic dependency rate	positive
Total area of irrigated plots (Ha)	negative

Source: Authors' calculations using EHCVM and DAPSA data

Annex 4: The indicators considered for constructing the adaptive incapacity index.

Indicators	Correlation sens with VCC
% household having received transfer	negative
% household having sent transfer	positive
% household received Government / NGO cash transfers	negative
Households with access to credit (%)	negative
% household with improved seed variety	negative
% household use of animal waste	negative
% household use of household waste	negative
% household use of inorganic fertilizer	negative
% household use of phytosanitary products	negative
% household that practiced multiple cropping	negative
% household with irrigated plot	negative
% household with water access	negative
% household with electricity access	negative
Female entrepreneurship index	negative
Proportion of household heads using agricultural information	negative
Households having developed shock adaptation strategies (%)	negative
Households having processed agricultural products (%)	negative
Households members of an association or cooperative (%)	negative
Proportion of women with access to agricultural land by region (%)	negative
Proportion of households with access to private veterinary services	negative
Proportion of households with vaccinated animals	negative

Source: Authors' calculations using EHCVM and DAPSA data

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