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Full Length Research Paper

Enhancing governance and processes for food security resilience to climate risks in Burkina Faso: an attempt toward developing vulnerability-mapping tools

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Abstract

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For many territories around the world, one of the threats linked to climate change would be increased pressure from disaster risks on economic and social development. Over the past decades, progress in the areas of early warning, response, disaster recovery and structural vulnerability management has been made in the Sahel region, particularly in the Food Safety. However, for Burkina Faso, the climate still induces serious constraints on social and economic development. This persistent effect of the climate results from various shortcomings in the solutions to reduce the vulnerability implemented, and more decisively from the structural challenges of the governance of disaster risks. One response to this threat is the promotion of better resilience to disaster risks, by improving the scientific bases, methodological and decision-making aspects of resilience processes and actions, developed in this article. The methodology used to develop these tools consists of a scientific approach based on the ClimProspect model coupled with a participatory approach involving the relevant stakeholders.

Keywords: Vulnerability, resilience, food security, Burkina Faso, Sahel**.**

INTRODUCTION

The agricultural sector plays a major economic and social role in ensuring sustainable food and nutritional security for the population of Burkina Faso. Agro-sylvo-pastoral, wildlife and fishery productions account for more than 86% of the population and represent the main sources of food and income. The main food crops account for more than 88% of the land area sown annually. The contribution of this sector to the gross domestic product (GDP) was estimated at around 30% in 2016 (INSD, 2016). In order to support and consolidate the development of this sector, various national and regional initiatives in the form of policies, reforms, plans and programmes have been implemented.

At the national level, such initiatives include, among others, the Structural Adjustment Program in the Agricultural sector (MARH, 1996), the Strategic Framework for the Fight

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against Poverty (MEFD, 2000), the Rural Development Strategy (MAHRH, 2003), the National Plan for the Organization and Coordination of Emergency Relief and Rehabilitation (MASSN, 2004), the National Programme for Agricultural Extension and Advisory Support (MAAH, 2012). Initiatives also include the Strategy for Accelerated Growth and Sustainable Development (MEF, 2012), the Food Security Information System (MAAH, 2012), the National Policy for Land Security in Rural Areas (MAAH, 2012), the Food Security Support Fund (MAAH, 2013), the National Economic and Social Development Plan (MEFD, 2016), the Response and support Plan for Vulnerable People to food insecurity and malnutrition (MAAH, 2017), the National Food and Nutrition Security Policy (MAAH, 2017) and the 2nd National Rural Sector Programme (MAAH, 2018).

At the regional level, the Comprehensive Africa Agriculture Development Programme (CAADP) is the main programme across the continent contributing to the development of agriculture in Burkina Faso. CAADP, which is a strategy aiming at transforming African agriculture and combating poverty and food insecurity in a sustainable manner, has been supported by the African Union's (AU) New Partnership for Africa's Development (NEPAD). Pursuant to the Maputo Declaration in 2003, this programme encourages African governments to allocate at least 10% of the share of their national budgets to agriculture in order to reach an agricultural growth of at least 6% per year. In addition, the African Agriculture Adaptation to Climate Change (African Union, 2016) initiative is a further effort towards addressing food insecurity. In Burkina Faso, the PNDES is one of the implementation frameworks for CAADP and AAA. It is the unique reference framework for the mobilisation of both domestic and external financial resources and for the intervention of the different stakeholders in the agricultural sector.

However, the analysis of the interannual food crop production in Burkina Faso shows that these multiple initiatives for the development of the agricultural sector have not yet generated sufficient resilience to eliminate climate impacts on food security.

Indeed, agriculture in Burkina Faso is still strongly marked by various constraints, including climate change, continuous land degradation and the high cost of efficient techniques and technologies. This situation hinders the achievement of food security.

The connection between annual agricultural production and food crises is one of the main illustrations of these adverse effects. For instance, some localities in the Sahel region and Burkina Faso were particularly hit by droughts, food crises or famine respectively in 1973, 1985, 1996, 1998, 2001, 2005, 2010 and 1987, 1999, 2002, 2004, 2007, 2009 (CILSS, 2004; SP/CNDD, 2016; Neya and al.; 2018). These cereal deficits have negatively influenced the capacity of Burkina Faso to develop policies. Food crises fundamentally prevent agriculture from contributing to ensuring food security and to developing endogenous capacities for an investment in social and economic development.

In order to sustainably achieve the development goals in the sector of food security, agricultural policies in Burkina Faso and western Africa, need to efficiently integrate considerations relating to resilience to climate and disaster risks. "Such integration is all the more necessary because if no action is undertaken, climate change will lead to a 50% drop in rain-fed agricultural yields in Africa by 2020 (IPCC, 2007), threatening and preventing food security in Burkina Faso. The Fourth Report on the State of the Environment in Burkina Faso (SP/CNDD, 2016) considers cost relating to environmental degradation and mainly resulting from climate impacts to be relatively high. According to the EconEnv approach used, this cost is estimated at around 780.39 billion CFAF (US$1.7 billion), or 21.2% of the country's Gross Domestic Product (GDP).

Therefore, in Burkina Faso's current context, taking into account considerations linked to disaster risks and climate change in development strategies and policies for the food security sector requires the challenge of the availability of knowledge and robust scientific decision-making tools to be met in line with the local environmental, social, economic, technological, institutional and political context.

As (Badolo, 2015; Gahiand et al., 2015), this contribution, based on expert judgment and the perception of food security actors at the national level, has the main objective of making an exhaustive mapping of the vulnerability factors of all components of food security in Burkina Faso in order to develop the appropriate resilience paths and allow an effective adjustment of agricultural development initiatives at local and national level.

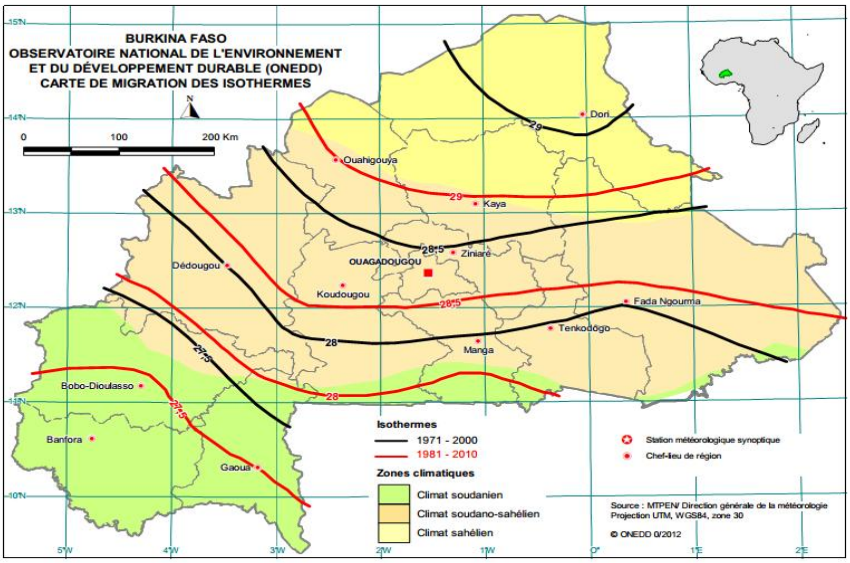
MATERIAL AND METHODS

The methodology implemented to collect information used in the development of the reference framework provided in this paper takes into account the contextual aspects of food security vulnerability to climate and disaster risks. It therefore combines an innovative scientific approach with a participatory approach involving relevant stakeholders (Badolo, 2015).

Presentation of the study area

The study was carried out in Burkina Faso in the sub-Saharan region of western Africa (Figure 1). Burkina Faso has a predominantly Sudano-Sahelian tropical climate, characterized by a long dry season alternating with a short rainy season. There are three climatic zones with regressive rainfall from south to north (SP-CNDD, 2016), ranging from less than 600 mm (about 25% of the territory) to between 600 mm and 900 mm (50% of the territory) and more than 900 mm (25% of the territory).

Figure 1. Study agro climatic zone map.



Source: ONEDD

This situation, as illustrated in Figure 1 above and Figure 2 below, suggests a worsening of climate and environmental constraints on the national economy, including the country's agricultural production capacity with a view to ensure food security.

In addition, Burkina population, estimated at 19,034,397 inhabitants in 2016, could reach 21,510,181 in 2020 (INSD, 2016). For an average density of 61.3 hbts/km^2 with a high occupation rate in biggest areas with high agricultural potential, the efforts made to achieve food security in the country remain fruitless (SP/CNDD, 2016). Indeed, over a quarter of the territory considered to be fairly wet and conducive to agricultural production, anthropic pressure on natural resources reduces any hope of achieving food security in Burkina Faso (Belem et al., 2018; Neya et al., 2019).

Considering the economic aspect and the well-being of the population, Burkina Faso is considered to be one of the poorest countries in the world (183rd out of 188th in the world, UNDP, 2016). This indicates the country's extreme vulnerability to the adverse effects of climate and disaster risk (MEFD, 2016).

Study approach

The approach considered in this study addresses the vulnerability of food security and includes climate threats commonly experienced in Burkina Faso, namely droughts, floods and pest attacks. The different components of food security consist as follows: (i) availability, (ii) affordability, (iii) stability (national distribution system), (iv) nutritional and sanitary use (food quality) and (v) governance.

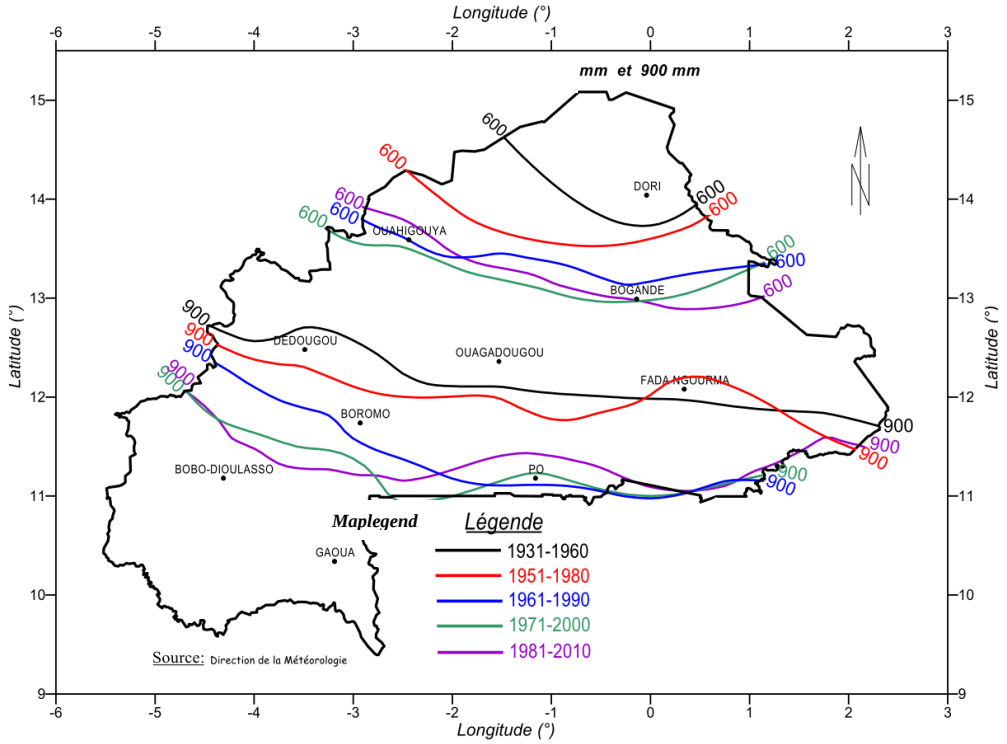
ClimProspect methodological framework

The methodological approach considered to generate reference frameworks includes the ClimProspect model (Gahiand et al., 2015; Badolo, 2015). Several authors have attempted to define the notion of vulnerability (Jiang et al., 2018; FAO, 2015; Palazzo et al., 2016). However, ClimProspect considers the vulnerability of a given system to be associated with the characteristics of the system itself or with the characteristics of the environment in which the system is located.

In this study, ClimProspect (Badolo, 2015) will be used with the expert judgement method, the method of forecasting by analogy and qualitative climate change scenarios for the development of climate change vulnerability reference frameworks. This is a flexible methodological framework favouring the use of several scientific investigation methods such as the expert judgement method, the forecast by analogy method, the applications of geographic information systems or quantitative methods, in particular through impact, vulnerability or resilience models and a participatory approach.

Schematically, the different methodological units respectively make it possible to: a) define the basic parameters of the study (mathematical analogues of risk mapping systems); b) develop reference frameworks for the impacts of climate risks (impacts table, impact spectra, socio-economic impact envelopes, impact categories); c) develop reference frameworks for vulnerability to these climate risks (Table of vulnerability factors, vulnerability factor spectra, socio-economic vulnerability envelopes, vulnerability factor categories, vulnerability indicators and d) generate categories of resilience needs for the systems

Figure 2. Isohyet migration.



Source :*MeteorologyDepartment*

under consideration. Figure 3 is a schematic illustration of ClimProspect's methodological units.

Figure 4 describes ClimProspect implementation in the development of the different decision-making reference frameworks.

It should be noted that for the specific case of this article, the results are based on vulnerability baselines caused by the main impacts of climate change on food security in Burkina Faso.

ClimProspect methodology requires two input variables composed of the system vector (e) and the risk vector (r).

The e vector (e1, e2, ...,em) is a mathematical analogue or equivalent of the system under study. The components e1, e2, ...,em of (e) are defined as the main components of the system under study.

The dimensions of food security in Burkina Faso which will be considered in this study are respectively food availability, food affordability, agricultural products' marketing systems, food utilization (nutrition - health - food quality) and food security governance. They are used to specify the components of vector (e), at the scale

m = 5 and consist as follows:

- e1=food availability ;
- e2= food affordability;
- e3= agricultural products' marketing systems;
- e4= food utilization (nutrition - health - food quality);
- e5=food security governance.

Vector (e) associated with food security in Burkina Faso is thus a five-dimensional vector. This indicates that the configurations of vulnerabilitý or resilience of food security in Burkina Faso are to be searched in practice in a dimension five state space.

Components of the climate risk vector r (r1, r2, ...,rk) include the climate and disaster risks which recurrently and significantly affect the system under study. The adverse effects of climate risks on food security in Burkina and elsewhere have been the subject of several studies based on scientific or participatory approaches (FAO, 2011; IPCC, 2007). With particular reference to Burkina Faso's national action plan for adapting to climate change (MERH, 2015), which was developed from a participatory process involving grassroots populations, we have selected the following components of vector r:

- r1= droughts ;
- r2= floods ;
- r3= parasitic attacks.

These components of vector r also cover the risks perceived and expressed in order of importance by stakeholders when collecting information in the field.

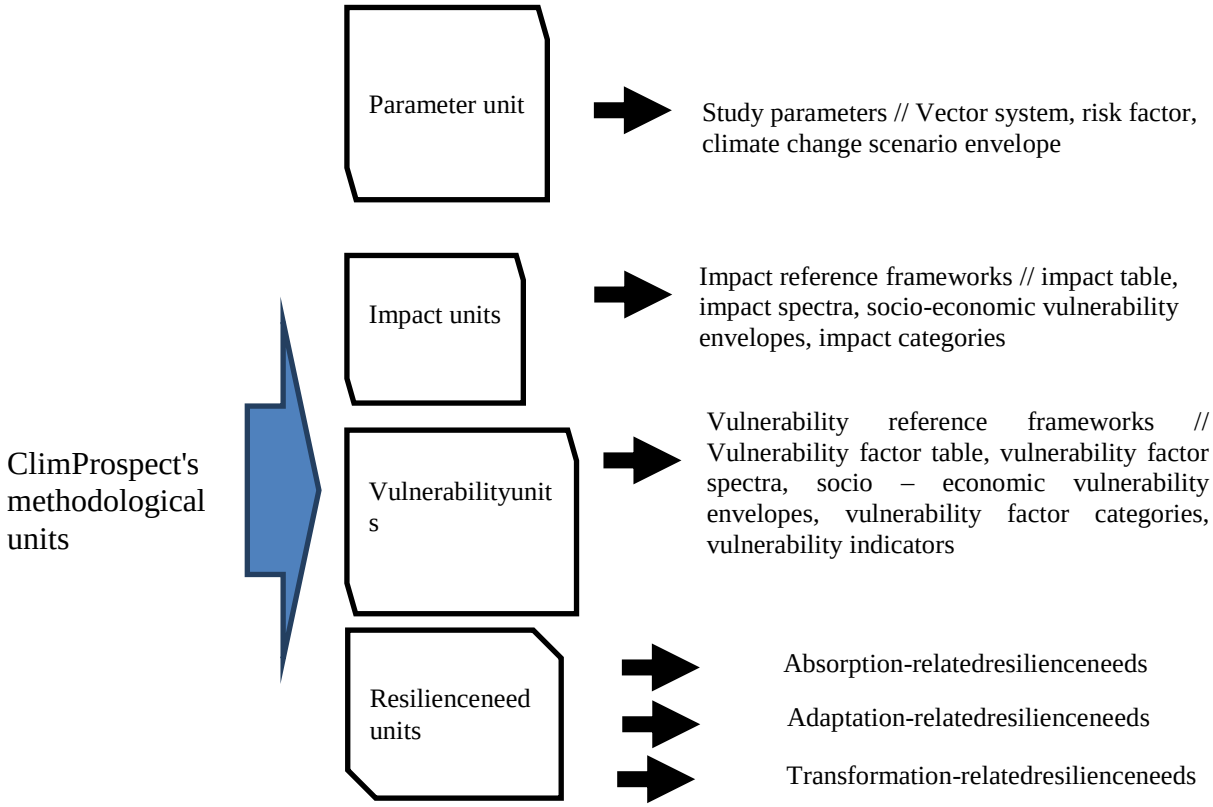
The "impacts" unit enables several categories of reference frameworks or subsets of impacts of climate risks on the system under study to be developed with respect to food security.

The first set of impact reference frameworks includes impact chains.

For a component e_i (i = 1, 2, ..., 5) of the vector (e) and a component r_j (j = 1, 2, 3) of the risk vector r, an impact chain is established as follows:

cij = $e_i r_j d_0$, $e_i r_j d_1$, ..., $e_i r_j d_p$

Figure 3. Schematic illustration of ClimProspect's methodological units.



Source: Cres, 2018

P refers to the length of the chain and:

- *1 °) $e_i r_j d_0$ to the direct impact of r_j on e_i ;*
- *2) $e_i r_j d_1$ tothe indirect impact of order 1, it is the most important immediate impact of eirjd1 ;*
- *3) eirjd2 to the indirect impact of order 2, is the most important immediate impact of eirjd1 ;*
- *p °) $e_i r_j d_p$to the indirect impact of order p, it is the most important immediate impact of eirjd (p-1).*

The second set of reference frameworks or subsets of impacts includes impact categories. For a climatic risk rj (j= 1, 2, 3), a category of impacts of order h (h=1, 2, ...,p) is a vector established as follows:

$fr_j d_h = (e_1 r_j d_h, e_2 r_j d_h, \ldots, e_k r_j d_h)$

As a reminder, p refers to the length of the impact chains.

A category of impacts is made up of impacts of the same order of a climate risk on, respectively, components e1, e2, … , e5 of vector (e), which is associated with food security.

The third set of reference frameworks or subsets of impacts relates to specific impact reference frameworks.

For a risk $r_{j\ (j=\ 1,\ 2,\ 3),}$ a specific impact frame of reference $dr_j e$ is the subset made up of the direct and indirect impacts of $r_{j.}$ It is obtained by the sum (union) of impact chains.

In this case, three specific impact reference frameworks have been developed:

- *dr1e = c11∪c21U c31U c41U c51*
- *dr2e = c12U c22U c32U c42U c52*
- *dr3e = c13U c23U c33U c43U c53*

The fourth set of impact reference frameworks includes the global climate risk impact reference, dre. It is the sum of all the specific impact reference frameworks

The fifth set of impact reference frameworks consists of socio-economic impact envelopes:

- dre_social = {social type impacts}
- dre_environemental= {environmental type impacts}
- dre_economic = {economic type impacts}
- dre_institutionnal = {institutional type impacts}
- dre_political = {political type impacts}

In this paper on climate vulnerability, the focus is to be put on vulnerability unit favouring the establishment of several reference categories of vulnerability factors to climate risks with regard to the system under study.
The first set of vulnerability factors includes vulnerability factor cells. A vulnerability factor cell vij is the subset of vulnerability factors to be addressed to mitigate impacts under the impact chain cij.
The second set of vulnerability reference frameworks relates to vulnerability factor categories: for a climate risk rj, a vulnerability factor categoryvrjdhrefers to the subset of factors to be addressed in relation to the impact categorydrjdh.
The third set of impact reference frameworks relates to specific references of vulnerability factors.
For a risk rj, a specificvulnerability factor reference vrje include the subset of vulnerability factors to be addressed in connection with the impact reference drje.
The fourth set of vulnerability factor reference refers to the global vulnerability factor reference. It is the sum of all the specific reference frameworks of vulnerability factor.
The fifth set of vulnerability factor of reference frameworks consists of the socio-economic vulnerability factor envelopes, composed as follows:

- dre_social = {social type impacts}
- dre_environmental = {environmental type impacts}
- dre_economic = {economic type impacts}
- dre_institutional = {institutional type impacts}
- dre_political = {political type impacts}

The “resilience needs” unit enables the development the three categories of food security resilience needs, as shown in Figure 5.

Data collection

In order to put the provided decision-making reference frameworks in context, a survey was conducted among the main institutional stakeholders in charge of food security governance in Burkina Faso.
Sixteen (16) organisations were selected on the basis of their commitment and professional affiliation (state institutions, diplomatic representations, multilateral organisations and civil society organisations). According to the conclusions drawn from the 5th IPCC report (IPCC, 2014), organisations with a prospective vision of climate change impacts on food security (Brunelle, 2015) will have more relevant solutions to suggest. A qualitative approach based on focus group interviews according to the methods of Agossouand et al., 2012; Krueger and Casey 2015, and Oyekaleand et al., 2015, was used.
The information collected focused on the direct and indirect impacts of climate risks on agricultural production (food availability), state financing of food security and governance of the food security sector (institutions and mechanisms). MS-Excel software was used for the analysis and processing of the collected information.

RESULTS

Specification of current vulnerability

Basic variables

As mentioned in the methodology, dimensions of food security in Burkina Faso considered in this study respectively include agricultural yields, food availability, the affordability of this resource (people's own capital), stability of the national distribution system of the resource (food prices on local markets), nutritional and sanitary (food quality) use of food and governance of the food resource (institutions, operating mechanisms). They are used to specify the components of vector e, consisting as follows:

- e_1 = availability ;
- e_2 = economic accessibility ;
- e_3 = stability of the national distribution system ;
- e_4 = use (nutritional-health (food quality) ;
- e_5 = governance.

Vector (e) associated with food security in Burkina Faso consequently refers to a five-dimensional vector. This indicates that the configurations of vulnerability or resilience of food security in this country are to be sought in practice in a dimension five state space.
Climate risk impacts on food security in Burkina Faso and elsewhere have been the subject of several studies based on scientific or participatory approaches (SP/CNDD, 2016; MERH, 2015; IPCC, 2014; FAO, 2011; IPCC, 2007). With particular reference to the National Action Plan for Adaptation to Climate Change (NAP in 2015), developed from a participatory process involving grassroots populations, the following elements were selected as components of vectorr:

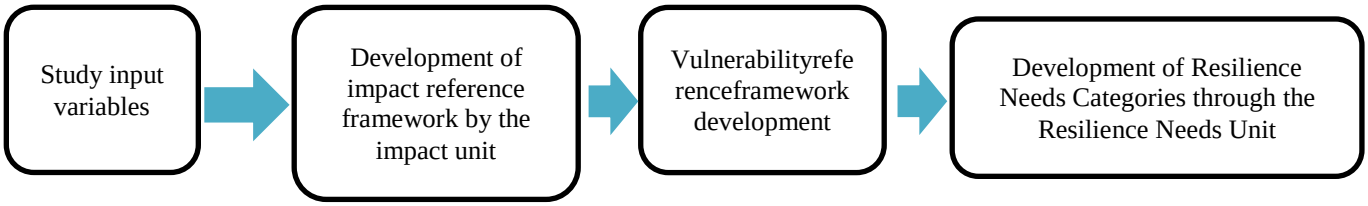
- r_1= droughts ;
- r_2= floods ;
- r_3= parasitic attacks.

These components of the vector “r” also refer to the risks perceived and expressed by the stakeholders when collecting information in the field.
It shows that in Burkina Faso, the most significant risk to food and nutrition security in terms of frequency and magnitude of impact is drought followed by flooding. Regardless of the climatic risk which occurs (drought and flooding), availability (food production) is the most sensitive component (Yigo, 2011).
The results provided in this paper are related to drought risk. Specifying a resilience path means establishing three vulnerability factors of reference frameworks.

Vulnerability frameworks

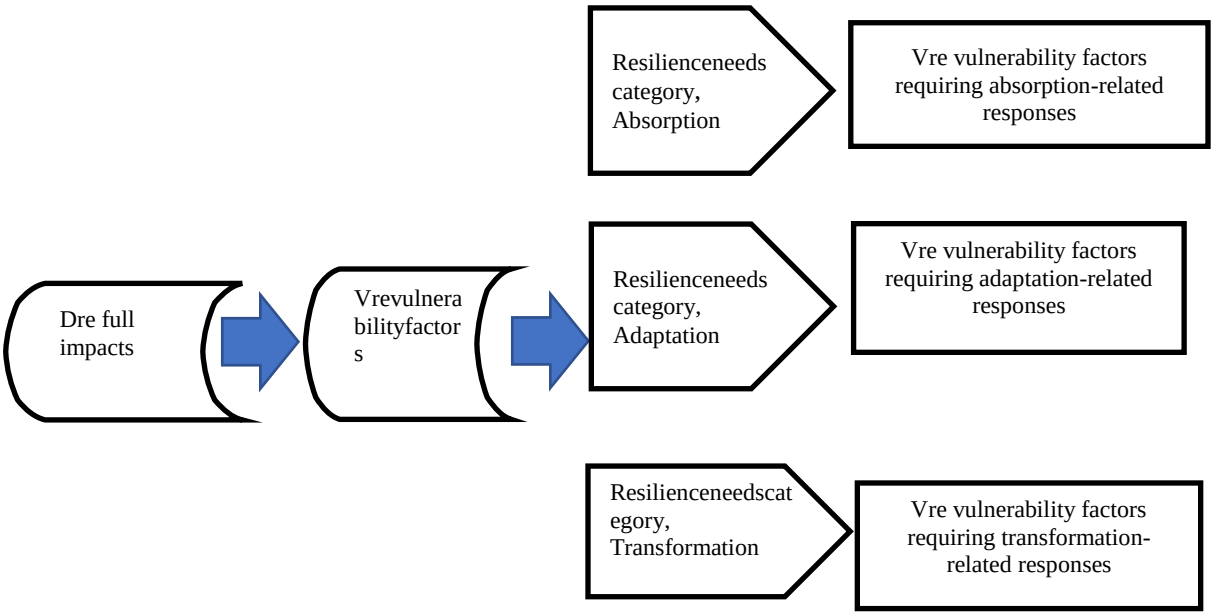
Several definitions of vulnerability can be provided in the literature. However, this paper considers the effects of a climate risk on a given system “S” to be a measure of the vulnerability of “S” to this risk.

Figure 4. ClimProspect implementation diagram



Source: Cres, 2018.

Figure 5. Diagram for the development of resilience needs categories.



Source: Cres, 2018.

Vulnerability is the essential information for adjusting development policies and initiatives in response to climate and disaster risks. Vulnerability may include economic, social, environmental, scientific, technological, institutional or political aspects. According to Badolo (2015), impacts are normally associated with vulnerability.

Generally, the vulnerability of a system to a risk suggests the possibility of such system to be damaged when this risk occurs. It is the result of a combination of a series of factors.

In this paper, impact reference frameworks, including the impact table, are to be used to demonstrate the vulnerability of the food security sector to climate risks in Burkina Faso.

The basic vulnerability reference framework is table 1 in which vulnerability factors are displayed. It describes the vulnerability factors V(i, j) which explain the impacts of the risk ri on the ej component, i.e. the elements of the IMP cell (i, j), *i = 1, 2, 3 and j = 1, 2, 3, 4, 5.*

V (i, j) = {riejd0V1, riejd0V2, riejd1V1, riejd1V2, riejd2V1, riejd2V2, riejd3V1, riejd3V2, riejd4V1, riejd4V2}, i = 1, 2, 3 and j = 1, 2, 3, 4, 5.

Table 1 is not a decision-making tool which can be used as it is displayed. As a result, it is derived from the vr_1e set, obtained by uniting the components vcij (i = 1, 2, 3, 4, 5; j = 1, 2, 3). It is the spectrum of factors of vulnerability of food security to climatic risks under the vector r1 in relation to drought in Burkina Faso. However, we note (Semdeand et al., 2020) that there is a correlation between the perception of food security managers in Burkina Faso and the scientific approach.The elements under vr_1e refer to the elements of vulnerability that the impacts of drought reflect on the components of food security and their repercussions. These include:

vr1e={ rain-fed nature of agriculture; deficiencies in the diversification of national economy with regard to increasing social assistance needs in the event of drought; deficiencies in institutional leadership to strengthen

Table 1. Matrix of vulnerability of system S to risk vector R.

Escomponant vector	Climate risks		
	r1	**r2**	**r3**
e1	r1e1d0V1 ; r1e1d0V2 ; r1e1d1V1 ; r1e1d1V2 ; r1e1d2V1 ; r1e1d2V2 ; r1e1d3V1 ;r1e1d3 V2 ; r1e1d4V1; r1e1d4V2	r2e1d0V1 ; r2e1d0V2 ; r2e1d1V1 ; r2e1d1V2 ; r2e1d2V1 ; r2e1d2V2 ; r2e1d3V1 ; r2e1d3V2 ; r2e1d4V1; r2e1d4V2	r3e1d0V1 ;r3e1d0V2 ; r3e1d1V1 ; r3e1d1V2 ; r3e1d2V1 ; r3e1d2V2 ; r3e1d3V1 ;r3e1d3 V2 ; r3e1d4V1; r3e1d4V2
e2	r1e2d0V1 ; r1e2d0V2; r1e2d1V1 ; r1e2d1V2 ; r1e2d2V1 ; r1e2d2V2 ; r1e2d3V1 ;r1e2d3 V2 ; r1e2d4V1; r1e2d4V2	r2e2d0V1 ; r2e2d0V2 ; r2e2d1V1 ; r2e2d1V2 ; r2e2d2V1 ; r2e2d2V2 ; r2e2d3V1 ; r2e2d3V2 ; r2e2d4V1; r2e2d4V2	r3e2d0V1 ; r3e2d0V2 ; r3e2d1V1 ; r3e2d1V2 ; r3e2d2V1 ; r3e2d2V2 ; r3e2d3V1 ;r3e2d3 V2 ; r3e2d4V1; r3e2d4V2
e3	r1e3d0V1 ; r1e3d0V2; r1e3d1V1 ;r1e3d1V2 ; r1e3d2V1 ;r1e3d2V2 ; r1e3d3V1 ;r1e3d3 V2 ; r1e3d4V1; r1e3d4V2	r2e3d0V1 ; r2e3d0V2 ; r2e3d1V1 ; r2e3d1V2 ; r2e3d2V1 ; r2e3d2V2 ; r2e3d3V1; r2e3d4V1; r2e3d3 V2; r2e3d4V2	r3e3d0V1 ; r3e3d0V2 ; r3e3d1V1 ; r3e3d1V2 ; r3e3d2V1 ; r3e3d2V2 ; r3e3d3V1 ;r3e3d3 V2 ; r3e3d4V1; r3e3d4V2
e4	r1e4d0V1 ; r1e4d0V2; r1e4d1V1 ; r1e4d1V2 ; r1e4d2V1 ; r1e4d2V2 ; r1e4d3V1 ;r1e4d3 V2 ; r1e4d4V1; r1e4d4V2	r2e4d0V1 ; r2e4d0V2 ; r2e4d1V1 ; r2e4d1V2 ; r2e4d2V1 ; r2e4d2V2 ; r2e4d3V1 ;r2e4d3 V2 ; r2e4d4V1; r2e4d4V2	r3e4d0V1 ; r3e4d0V2 ; r3e4d1V1 ; r3e4d1V2 ; r3e4d2V1 ; r3e4d2V2 ; r3e4d3V1 ;r3e4d3 V2 ; r3e4d4V1; r3e4d4V2
e5	r1e5d0V1 ; r1e5d0V2 ; r1e5d1V1 ; r1e5d1V2 ; r1e5d2V1 ; r1e5d2V2 ; r1e5d3V1 ; r1e5d3V2 ; r1e5d4V1; r1e5d4V2	r2e5d0V1 ; r2e5d0V2 ; r2e5d1V1 ; r2e5d1V2 ; r2e5d2V1 ; r2e5d2V2 ; r2e5d3V1 ; r2e5d3V2 ; r2e5d4V1; r2e5d4V2	r3e5d0V1 ; r3e5d0V2 ; r3e5d1V1 ; r3e5d1V2 ; r3e5d2V1 ; r3e5d2V2 ; r3e5d3V1 ; r3e5d3V2 ; r3e5d4V1; r3e5d4V2
S System considered	**Envelope of the most significant vulnerability factors**		

Source: Cres, 2018.

mechanisms to prevent the risks of weakening national trade policies in place in the event of drought; deficiencies in economic investments to create remunerative employment considering increased migration flows to neighboring countries/gold mining sites in the event of drought; deficiencies in economic investments to secure road infrastructure in the event of drought; deficiencies in economic investments to secure existing food habits with the development of new habits in the event of drought; deficiencies in economic investments in the transport sector regarding increasing costs of food products transported in the context of drought; deficiencies in economic investments to ensure national stability in the event of drought; deficiencies in economic investments to compete in the foreign market during periods of drought; deficiencies in the economic systems for controlling food prices in drought situations; insufficient economic means granted to the Executive Secretariat for Food Security (SE/SA/MAAH) for managing the risks of food insecurity in drought situations; shortcomings in the resources required for post-disaster recovery with the increase in consultation frameworks in the event of drought; shortcomings in public policies in relation to the consequent budget estimate for food security considering drought risks; shortcomings in public policies in relation to the response to nutritional diseases in the event of drought; shortcomings in public policies for securing national food security institutions regarding drought risks; the degraded state of agricultural land; structural weakness of the social fabric; inadequacies in economic investment in mechanisms for making agricultural products available in drought situations; inadequacies in economic investments to secure income-generating activities considering the deterioration of the nutritional qualities of food in the event of drought; inadequacies in economic investments to support income-generating activities considering the amplification of conflicts between stakeholders over natural resources in the event of drought; Insufficient economic investment considering the increasing need for specific funding for agriculture in drought situations; insufficient economic investment to build highly weather-resistant infrastructure in drought situations; insufficient mechanisms for preventing and managing social conflicts in drought situations}.

The whole vr_1e shows that vulnerability of food security in Burkina Faso to recurrent droughts is the result of a combination of the characteristics of this sector and the economic, environmental, social, scientific, technological, institutional and political characteristics of the country.

For decision-making toolrelated to disaster risk prevention and management, four vulnerability categories V1, V2, V3 and V4 are derived from Table 1.

V1 vulnerability category relates to early warning.
In order to make it a decision-making tool for disaster risk prevention and management, four vulnerability categories V1, V2, V3 and V4 are derived from the spectrum of vulnerability factors, which are sets of vulnerability factors. These relate respectively to warning, response, recovery and structural vulnerability. The elements of the categories, resulting in each of these cases from a synthesis of scientific analysis, are the vulnerability factors to be addressed to reduce the impact of climate on food security in Burkina Faso.
By addressing vulnerability under V1, the context is oriented towards developing and implementing early warning solutions relevant to agriculture, which represents one of the pillars of food security in Burkina Faso. The identified factors of vulnerability under V1 consist as follows:
V1 = { poor performance of the early warning system on food security; shortcomings in the early warning mechanism for flood risks in the agricultural sector; deficiencies in the early warning and monitoring system on the migration of locust pests; deficiencies in the early warning system for drought risks}.
According to the Global Climate Observing System (GCOS/WMO, 2016), African states in general and those of the Sahel in particular, although well exposed to the effects of the climate, still face major difficulties in setting up efficient, operational and structuring early warning mechanisms for nations. Burkina Faso has just worked out its first initiatives two years ago (SP/CNDD, 2016). These difficulties call for the consideration of vulnerability factors under V1 to be considered among the priorities at national level.
Appropriate response mechanisms make it possible to significantly mitigate the indirect social and economic impacts of climate risks. V2 vulnerability categorycharacterizesthe relative vulnerability to the response for the study zone, providing indications for increasing response capacities in relation to the food security sector in Burkina Faso.
V2 = {Ineffectiveness of the response system in the event of food insecurity; inadequacies in the response mechanism in the event of flooding in the agricultural sector; inadequacies in the response mechanism in the event of pest attacks in the agricultural sector; inadequacies in the response mechanism in the event of drought}.
V2 vulnerability category elements refer toreference frameworks usedin the development and implementation of appropriate response solutions for the food security sector.
In environments with poor post-disaster recovery capacities, the indirect impacts of climate risks persist and provide fertile ground for the proliferation of poverty. In the case of Burkina Faso, V3 vulnerability category elements are the reference frameworks for building recovery capacities for the food security sector. These reference frameworks are composed as follows:
V3= {Ineffectiveness of post-flood recovery mechanism; inadequacies in the recovery mechanism for pest attacks; inadequacies in the recovery mechanism for drought}.
Vulnerability under V4 is a structural vulnerability. It is the main form of vulnerability which needs to be addressed to eliminate the impacts of climate in a given system. Factors contributing to structural vulnerability in food security sector consist as follows:
V4= {lack of adequate agricultural insurance; lack of regulations on farm locations in potentially flood-prone areas; lack of provisional budget for disaster risk; rain-fed nature of agricultural production; lack of information on crop pests; lack of knowledge on disaster management tools and mechanisms; lack of knowledge about the pace and extent of climate change and the nature of its impact on agriculture; lack of partnership between agriculture and financial institutions; lack of human resources for disaster risk management for the food security sector; deficits in climate information for agricultural production; isolation of national agricultural markets; poor economic access to improved seeds, fertilisers and irrigation facilities; poor economic access to plant health inputs; low development of farm household savings; low development of medium and long-term cereal stock practices; low development of off-farm income; low integration of climate and disaster issues into agricultural policies; poor integration of disaster risks in food security sector projects and programmes; poor consideration of water and soil conservation techniques; poor consideration of climate and disaster risks in MAAH budget lines; weak land tenure security; low adoption rate of water control techniques for agricultural production; low use of phyto-sanitary inputs; low use of fertiliser products; low use of improved seeds; poor trade policy instruments; low income for the development of farms; insufficient national security stock; insufficient development of agricultural areas; unproductive mechanism for the production and dissemination of improved seeds; low intensification of water management techniques for agricultural production; degraded state of agricultural land; low-skilled labour; multiple government priorities; insecurity of housing and storage facilities; insecurity of transport infrastructure; insecurity of road infrastructure, storage and processing of agricultural products}.
Effective vulnerability management under V4 is the main option for setting up the food security sector in a stable resilience configuration. Such elements contained in this package will serve as reference frameworks in the development of structural vulnerability management solutions.

Vulnerability indicator frameworks

A package of five vulnerability indicators is provided to monitor changes in the vulnerability of the food security

sector to climate risks in Burkina Faso. These indicators consist as follows:

- The proportion of degraded agricultural land in Burkina Faso;
- The proportion of Burkina households with access to sufficient and healthy basic food;
- The level of food distribution at the national level;
- The proportion of local market demand for cereals which cannot be met by local stocks in the medium and long term;
- The proportion of food security sector resilience needs addressed by development policies and strategies.

In the field, the use of these indicators requires the development of appropriate databases.

Climate change challenges

In the case of this study, two qualitative climate change scenarios S1 and S2 were used. S1 scenario anticipates a drier and warmer future climate compared to the current climate. It is mainly characterized by a significant increase in temperature and permanent drought. S2 scenario projects a highly variable future climate compared to the current climate. The latter is characterized by an increase in temperature and a significant increase in the frequency and intensity of climatic shocks (droughts, floods).

Under a climate such as the one anticipated by the S1 scenario, major challenges were identified for the food security sector in Burkina Faso. Such challenges include the shortage of water for agricultural production, the loss of agricultural land, the increase in the cost of agricultural production, the loss of profitability of food crops, the increase in the cost of agricultural credit, higher qualification requirements from agricultural producers, higher performance requirements from agricultural institutions and policies and greater needs in technology and scientific knowledge.

If in the long term Burkina Faso's climate is stillcharacterizedaccording to the projections observed in the S2 scenario, some of the challenges that food security planning should consider will include increased degradation and reduction of agricultural land area, significant fluctuation of agricultural water, higher costs of agricultural credit, more stringent requirements of openness to foreign markets, greater demands on the performance of road and market infrastructures, greater demands on the capacity to build up food security stocks, greater demands on the qualifications of agricultural producers, greater demands on the performance of food security institutions and policies, greater needs in terms of technology and scientific knowledge.

The concept of no-regret adaptation was used to identify the challenges that climate change will pose to achieving food security in Burkina Faso, regardless of these changes. These challenges consist of V5 future vulnerability category elements:

V5={huge difficulties in collecting water for agricultural production; losses in the profitability of food crops; higher costs of agricultural credit; increased demands for openness to foreign markets; gradual losses of productive agricultural land; increased demands for capacity to build up food security stocks; increased demands on the performance of road and market infrastructure; increased demands on the performance of food security institutions and policies; increased needs for technology and scientific knowledge; increased skill requirements from agricultural producers; higher costs of agricultural production}.

Resilience paths

In this paper, specifying a resilience path means establishing three reference frameworks for vulnerability factors. These reference frameworks relate respectively to sets of short, medium and long-term objectives aiming at reducing vulnerability.

For the food security sector in Burkina Faso, the short-term objectives for vulnerability reduction shall respectively relate to the improvement and strengthening of policies relating to wetland management and land security, economic mechanisms for post-disaster response and recovery, emergency humanitarian assistance mechanisms, access to early warning, transfer of new technologies for agricultural land regeneration and for water and soil conservation.

Regarding medium term objectives, efforts shall made in boosting the Food Security Support Fund and setting up a green fund for disaster risks, strengthening food security stocks, improving food supply conditions and improving agricultural yields. In addition, such efforts shall include the enhancement ofagro-forestry production, human and economic support to rural women, the revitalisation of disaster risk management bodies at the local level, and a better integration of climate and disaster risks into development strategies.

Long-term objectives for vulnerability reduction concernthe development of new production technologies adapted to climate and environmental changes,the strengthening of a savings culture, the reinforcement and support of community-based mutual insurance companies, and the increase of functional literacy in rural areas. Such objectives also call for the development of early warning systems for drought and flood risks in rural areas, the increase of traffic on infrastructures, the creation of an interface between agro-meteorology and agricultural extension services and producers. Furthermore, they suggest the intensification of research for the development of short-cycle and more drought-resistant varieties, the strengthening offood production mechanism, the reinforcement of non-timber forest products, and the reviewof the coordination of interventions by food security stakeholders.

DISCUSSION

In western Africa, particularly in the Sahel region, major knowledge gaps hindering the development, implementation and assessment of relevant processes for climate risk resilience relate to vulnerability (Paris, 2015; BanqueMondiale, 2013; FAO, 2015). One of the consequences of these deficits is the absence of consensual vulnerability frameworks for basic socio-economic sectors guiding resilience-building initiatives. In such a context, vulnerability frameworks provided in this paper can be considered as improvements in knowledge and decision-making capacities in relation to the integration of resilience considerations into food security policies and initiatives in Burkina Faso.

According to Badolo (2015), in Burkina Faso, analysis of specific vulnerability envelopes of the food security sector to disaster risk reveals eight types of vulnerability. These include environmental, economic, social, human, scientific, technical, institutional and political aspects. For the specific case of food security in Burkina Faso, the study reveals that economic vulnerability is predominant in this sector.

In practical terms and through various combinations of the vc_{ij} components (i = 1, 2, 3, 4, 5; j = 1, 2, 3) displayed in Table 1, different bodies of knowledge are built up on vulnerabilitý from food security to climate risks in Burkina Faso. The various vulnerabilitý frameworks provided in this paper stands as illustrations.

The same author (Badolo, 2015) noted that to be effective, actions to reduce the current climate influence on food security should be guided by vulnerability factors to climate and disaster risk. V1, V2, V3 and V4 vulnerability categoriesare decision-making tools which should make it possible to meet the challenge ofdeveloping efficient strategies and actions to reduce climate change impacts on food security in Burkina Faso. According to Sanou and Badolo (2017), specifically, V1, V2 and V3 categoriesrespectively indicate that: a) the inadequacies identified in the community early warning system are the main vulnerability factors to be addressed for a significant contribution of early warning to the eliminationof climate change impacts on food security. Such a system should be community-cantered, consider the specific needs of women and implement diverse partnerships; (b) the lack of community-based mechanisms for addressing pest attacks, shortcomings in the national plant protection mechanism, deficiencies in endogenous mechanisms for responding to cereal deficits and the lack of economic mechanisms for responding to the loss of income of farming households are the vulnerability factors to be consideredto strengthen people's response capacities to the effects of climate risks and disasters on food security; (c) to achieve a more significant contribution of post-disaster rehabilitation to food security resilience to disaster risk, the lack of community-based mechanisms for post-disaster recovery is the main vulnerability factor whichshould be efficiently targeted.Fundamentally, the persisting effects of climate on food security result from deficiencies in the management of the structural vulnerability to climate and disaster risks in this sector (Becerra, 2012). V4 category elements show that factors which combine to generate this structural vulnerability include environmental, economic, scientific, technological, human and social considerations. In practice, the reduction of these vulnerability factors: a) can only be envisaged through consistent planning of the efforts to be made over time; b) will require the contribution of multiple areas of expertise and significant financial resources; and c) will require the creation of a platform calling for the involvement of many stakeholders.

Taken together, the elements of the four vulnerability categories indicate that reducing the impact of climate and disaster risk on food security will require a combination of nationwide processes. At the national level, the process will consist in improving local people's access to the vulnerability reduction products and services offered by the different national systems.

The vulnerabilities of a given territory and its population are therefore inseparable from structural (hazards) and cyclical factors involving human factors such as the urbanization and occupation system of space, socio-economic, cultural, institutional and organizationalcontexts (Mac Carthy, 2012). Likewise, these vulnerabilities depend on subjective factors, referring to value systems including the stakes to be preserved, risk management and their perception/representation by the affected societies (Allio, 2012). Attempts to proactively build a resilient national system can lead to the development of a global vision of its future while considering its environment. This may not only lead stakeholders to invest in intelligent prevention, but also and above all to develop a long-term adaptive capacity of the national system, with respect to the socio-economic, environmental and institutional challenges which themselves evolve over time (Woloszynand Quinault, 2013). And in thisconstantly-changing world, national planners have to assess and consider updating conditions which are constantly changing as well.

Therefore, strategies and policies shall be designed to adapt to changing conditions. Despite both institutional and political injunctions and incentives to ensure food security, it is still rare for proactive/transformative national adaptation to be planned in advance (Berezinaandal, 2015; Semde and al., 2020) for people, especially the most vulnerable.

Overall, the results provided in this study should contribute toward improving the processes of food security resilience to disaster risk at the national level. In fact, such resultsprovide decision-making tools to: b1) encourage forum for dialogue between stakeholders involved in food security resilience; b2) set shared short, medium and long-term food security resilience objectives; b3) plan actions for building food security resilience over time; b4) establish

Regular reference frameworks for resilience; and b5) implementconsensual mechanisms for assessing progress made in terms of increasing resilience.

CONCLUSION

Developing and implementing efficient and effective resilience processes requires robust scientific information, especially in contexts where financial resources for resilience are limited. For the food security sector in Burkina Faso, the production of such information is one of the challenges for resilience.

This paper, aimed at developing decision-making tools in connection with disaster risk resilience for the food security sector in Burkina Faso, enabled through the implementation of the ClimProspect approach, to define vulnerability factors for this sector in Burkina Faso and to suggestdecision-making reference frameworks to build a sustainable configuration of resilience for food security.

Such reference frameworks are decision-making tools which can significantly contribute to the development, implementation and assessment of processes for food security resilience to climate risks, namely through adjustments to development policies and initiatives. Those frameworks improve current knowledge on the vulnerability of the food security sector to climate risks and should, in practice, make it possible to: encourage forum for dialogue between stakeholders involved in food security sector resilience, to set consensual short, medium and long-term resilience objectives, plan resilience-building actions over time, to establish regular reference frameworks for resilienceand implement consensual mechanisms for assessing progress made in increasing resilience.

Indeed, in the current context in the Sahel region, and particularly in Burkina Faso, improving disaster risk governance models is arguably one of the most encouraging alternatives for reducing the climate impacts on food security. The results provided in this paper are decision-making tools for improving national disaster risk governance with respect to food security in the country.

Considering their nature and relevance, the tools provided should make it possible to strengthen consultation frameworks for stakeholders involved in resilience, to plan resilience-building strategies over time and to establish regular resilience reference frameworks. This situation may result inmore participatory climate risk governance which is more focused on the populations and their resilience needs, gradually providing spacefor a sustainable food security. This is essential in order to associate national strategies with the existing ones at local level and, above all, to encourage resilience mechanisms throughout the country.

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