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Enhancing Food Security and Disaster Risk Resilience in Burkina Faso: New Resilience Pathways to Disaster Risk and Food Security in the Sahel for Public Action

Idrissa Semde[1], Samuel Yonkeu[2], Mathieu Badolo[3], Samuel Pare[4], Neya Tiga[5]

1. *Centre for Research and Studies in Management (CREM), Université Aube Nouvelle, 06 PO Box no. 9283, Ouagadougou 06, Burkina Faso*
2. *African Center for Scientific Research and Training (Cres), Ouagadougou, Burkina Faso*
3. *Center for Research and Studies in Management (CREM), Université Aube Nouvelle, 06 PO Box no. 9283, Ouagadougou 06, Burkina Faso*
4. *Université Joseph Ki Zerbo, Ouagadougou, Burkina Faso*
5. *Ministry of Environment, Green Economy and Climate Change, Burkina Faso*

Abstract

Context: *In Burkina Faso, food security is a sector in which resilience to climate and disaster risks should be addressed. The country's economy is essentially based on the rural sector and if nothing is done, the development in this sector could be severely handicapped by climate change, which changes rainfall pattern and increases extreme weather events. Therefore, this situation further compromises the achievement of food security. Robust scientific information is essential to develop and implement efficient and effective resilience processes.*

Material and methods: *the approaches considered to define information used in the development of the proposed reference frameworks in this paper include contextual aspects of food security resilience to climate and disaster risks. In addition, it associates a scientific approach with a participatory approach involving major stakeholders in food security management.*

Results: *the main results obtained from this study consist of a corpus of decision-making frameworks designed to improve governance and resilience processes in food security sector in Burkina Faso. Such frameworks include: impacts frameworks of climate change on food security, vulnerability frameworks of food security and resilience pathways.*

Conclusion: *The provided frameworks, the development of which is based on a robust methodological framework, are impact, vulnerability, vulnerability monitoring frameworks and resilience pathways. Such frameworks should make it possible to promote spaces in Burkina Faso for stakeholders involved in food security to develop and implement innovative resilience pathways in this development sector.*

Keywords: impact, vulnerability, resilience, food security, Burkina Faso, climate.

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I. Introduction

Significant findings from the Intergovernmental Panel on Climate Change (IPCC) strongly demonstrate that global warming is unequivocal (IPCC, 2001; IPCC, 2007; IPCC, 2013; IPCC, 2014). Sylla et al (2016) show in their study that most West African countries are expected to face shorter rainy seasons and longer drought periods with dire socio-economic consequences. According to some projections (Ouédraogo, 2012), a warming of 2.5°C would lead to a 46% drop in agricultural income in Burkina Faso by 2090-2099 while a rise in average annual temperatures of 5°C would lead to a 93% loss of income on average for all farms.

For many authors (MEFD, 2016; INSD, 2019), Burkina Faso, whose rural sector generated about 14.2% of the Gross Domestic Product in 2017 and employed about 80% of the active population, could be particularly affected by climate change. Indeed, the performance of the country's agricultural sector depend on a climate characterized by a significant rainfall deficit and a hostile environment. This rainfall, characterized by strong isohyet regressions towards southern regions, forces vulnerable populations to constantly move to agricultural-friendly areas to ensure their livelihoods (MAAH, 2017b; SP/CNDD, 2016).

In this context, food security remains a critical issue for Burkina Faso and while formulating its development policies, resilience solutions to the effects of climate change are to be seriously considered.

As many other authors (CILSS, 2004; FAO, 2012; FAO, 2015) argued, food security, from its quantitative vision before the 1970s to its multidimensional meaning today, remains a major issue for countries

such as Burkina Faso and compromises its development in the longer term. Indeed, considering climate change and its significant consequences, the issue of food security is becoming much more acute. People's capacities and strategies to access healthy and sufficient food were unsuccessful due to climate variations which obliged them to adapt or live in relatively precarious conditions (GIZ, 2015; ADB, 2015; Garth et al,. 2015).

Despite progress made through increased agricultural production over years and the development of national food security and nutrition policies, the problem of food and nutritional insecurity remains unresolved. Therefore, this situation lead us to question the effectiveness of these resilience strategies (MAAH, 2012a; MAAH, 2012b; MAAH, 2012c; MAAH, 2017a). Including disaster risk and climate change considerations into the development strategies and policies in food security sector requires the implementation of robust scientific knowledge and decision-making tools matching the local, environmental, socio-economic, technological, institutional and political context. (Semdé et al, 2021a; Badolo, 2015b).

Our study fundamentally aims at presenting a corpus of decision-making tools designed to improve governance and resilience processes in the food security sector in Burkina Faso.

The Climprospect approach used is innovative and generates impact, vulnerability reference frameworks, and resilience pathways. Developed basing on robust scientific information (Badolo, 2015a; Gahi et al., 2015), these frameworks are composed of decision-making tools designed to inform efficient adjustment of agricultural development initiatives nationwide in order to ensure food security in a context of resilience to climate risks. Taking into account local stakeholders 'views reinforces the contextual dimension of these tools.

II. Material Et Method

The methodology implemented to define the information used in the development of the reference frameworks provided in this paper takes into account the contextual aspects of food security resilience to climate and disaster risks. Therefore, it combines a scientific approach with a participatory approach involving local populations (Badolo, 2015a).

1. Study area and scope

The study area is Burkina Faso located in the sub-Saharan region of Western Africa. The map shows its location. Burkina Faso has a tropical climate with a predominantly Sudano-Sahelian climate, characterized by a long dry season alternating with a short rainy season. In this country, there are three climatic zones with decreasing rainfall from south to north (SP/CNDD, 2016; Neya et al., 2019), ranging from less than 600 mm (about 25% of the territory) to between 600mm and 900mm (50% of the territory) and more than 900 mm (25% of the territory).

This predominantly-dry climate, as illustrated in Figure 1, presages a significant slowdown in the national economy, including the country's agricultural production capacities meant to ensure food security (FAO, 2012; SP/CONEDD, 2010). This results in a need for resilience.

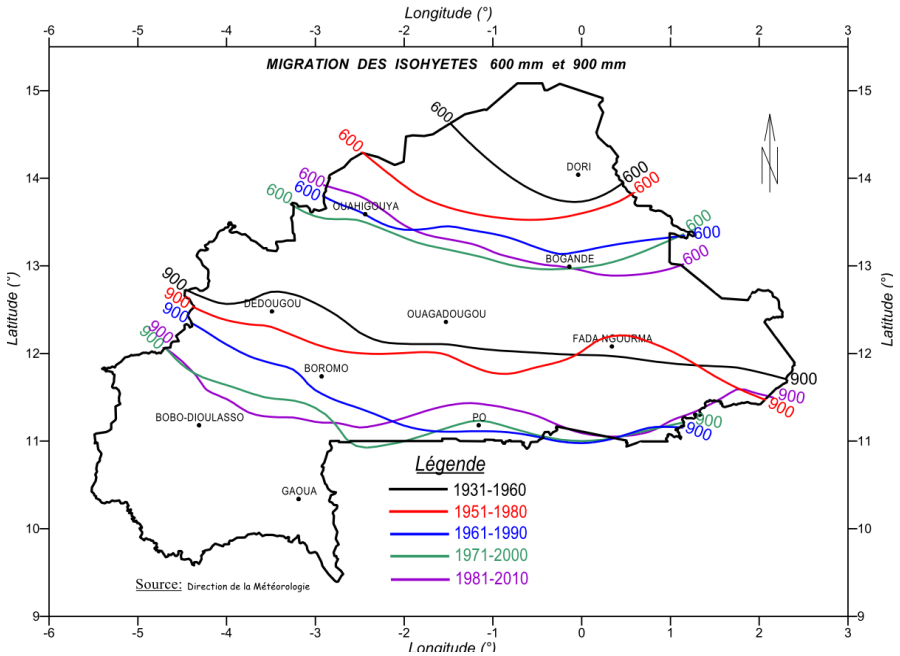


Figure 1 : Isohyet migration map in the study area.

Source : ONEDD

In addition, (INSD, 2020) Burkina population is estimated at 20,487,979 inhabitants (RGPH 2019), with an average density which increased from 51.4 inhabitants/km2 in 2006 to 75.1 inhabitants/km2 in 2019, and a high occupancy rate in areas with high agricultural potential.

This is another vulnerability factor which makes it uncertain whether the country will achieve food security (SP/CNDD, 2016). Indeed, in the quarter (1/4) of the territory that is fairly wet (900 to 1000mm), and conducive to agricultural production, two major phenomena also make these areas unproductive. These include anthropic pressure on natural resources and recurrent insecurity (terrorism), which force populations to move to safer areas, dispelling any hope of reaching food security in Burkina Faso (Belem et al., 2018).

With respect to economy and people's well-being, Burkina Faso's Human Development Index (HDI) value for 2019 was 0.452. This places the country in the "low human development" category and 182nd out of 189 countries and territories (UNDP, 2020).

This indicates the country's extreme vulnerability to the adverse effects of climate and disaster risk (MFED, 2016).

2. Study approach

The approach considered in this study consists in developing food security resilience pathways viewed through the prism of climate threats commonly experienced in Burkina Faso, namely droughts, floods and crop pest attacks. The study approach (es) refers to food security; its following dimensions will be considered in the coming analyses:

- e1= availability of food resources (national food crop production, cereal banks, food aid and imports) ;
- e2= economic accessibility to food resources (sale of agricultural cash crops, sale of market garden production, sale of livestock products and by-products, sale of fishery products, sale of forestry products, sale of handicrafts, sale of labour power, etc.) ;
- e3= stability of the distribution system (stability of food supply: (surplus from local agricultural production), availability in time (from one period to another) and space (from one region to another))
- e4= use (nutritional-health and food quality) and finally ;
- e5= food security governance (effectiveness and dynamism of food security management institutions).

It should be noted that es vector components are based on the environmental, economic, social, institutional and political profile of the study area, which is Burkina Faso. In addition to this clarification, food security traditionally comprises four components, but in this study the approach considered, especially Climprospect, integrates a fifth component which is the governance of food security institutions. The components of the climate risk vector r (r1, r2, ..., rk) include climate and disaster risks which recurrently and significantly affect the system under study. In Burkina Faso, the three (03) major climatic risks at r1, r2 and r3, which compromise food security refer respectively to drought, floods and locust attacks.

The identification of the three climate risks (r1, r2 and r3) was based on data from Burkina National Adaptation Programme of Action to Climate Variability and Change (NAPA) and Burkina National Adaptation Plan to Climate Change (NAP), relating to climate and disaster risks which affect people and their livelihoods. A matrix of sensitivities was established with stakeholders in the field. However, for practical reasons, in this work, the five (05) selected dimensions of food security will be analysed with the first major risk, namely droughts.

III. Research methods used

As part of this study, two complementary methods are used, namely, the scientific method and the participatory approach.

3.1. The scientific method

The scientific method used consists of the Climprospect model which is a methodological approach generally used for the development of climate change resilience pathways (Gahi et al., 2015). It is a flexible methodological framework favouring the use of several scientific investigation methods such as the expert judgement method, the method of predictions by analogy, the applications of geographic information systems or quantitative methods, through impact, vulnerability or resilience models. The figure below describes the approach used for its implementation in a case study.

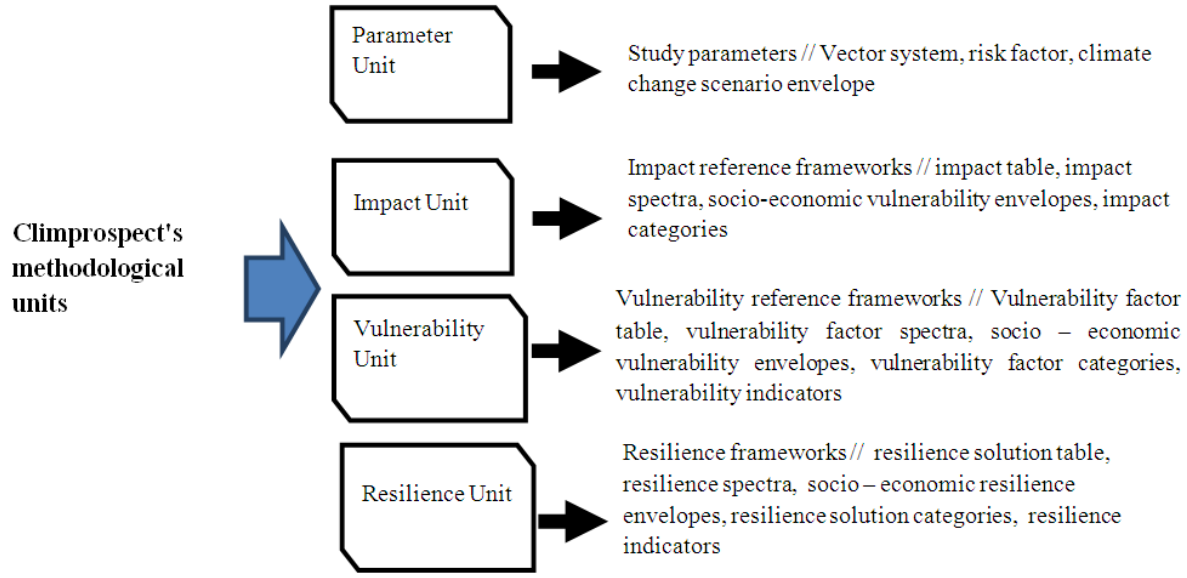


Figure 2: Climprospect's methodological unit diagram development

Through this methodology, the different methodological units respectively make it possible to:

- define the study parameters (mathematical analogues of risk-mapping systems ;
- develop climate risk impact frameworks (impact table, impact spectra, socio-economic impact envelopes, impact categories) ;
- develop vulnerability frameworks (vulnerability factor table, vulnerability factor spectra, socio-economic vulnerability envelopes, vulnerability factor categories, vulnerability configurations) ;
- develop resilience pathways (resilience solution table, resilience spectra, socio-economic resilience envelopes, resilience solution categories, resilience indicators) ;

The "parameter unit" establishes the basic parameters of the study which refer to the system vector (e), the risk vector (r) and the climate scenario vector (sc);

The vector e (e1, e2, ...em) is a mathematical analogue of the system under study. The components of (e) are the dimensions of the system under study taken as components in the study.

In this paper addressing food security, (m) = 5 and the components of the vector (e) are e1, e2, e3, e4 and e5 mentioned above in the study system.

Components of the climate risk vector 'r' (r1, r2, ..., rk) include the climate and disaster risks which recurrently and significantly affect the study system. In this paper, such components consist as follows:

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

For the identification of major climate impacts, a vector of climate scenarios was considered. This vector describes the climate profiles used to assess climate change impacts. The two qualitative scenarios considered are the following :

- **Scenario sc1:** this scenario anticipates a future climate which is dry and warm compared to the current one. It is mainly characterized by a sharp rise in temperatures, an decrease in rainfall, and a permanent drought ;
- **Scenario Sc2:** this scenario projects a highly erratic climate compared to the current one. It is characterized by an increase in temperature and a significant increase of climatic shocks (droughts, floods, heat waves, parasitic attacks on crops, etc).

Impacts units enabled the development of several sets of reference frameworks for the impacts of climate risks on the system under study.

1) The first set of impact reference frameworks includes impact chains :

For a component ei of (e) and rj of r, an impact chain formulates following this form:

cij = eirjdo, eirjd1, ..., eirjdp

p is the length of the chain and : 1°) eirjdo refers to the direct impact of rj on ei; 2°) eirjd1, ..., eirjdp is the indirect impact of rj on ei of order (1,.....p)

2) The second set of impact reference frameworks relates to impact categories :

For a climatic risk rj , a category of impacts of order (h) is a vector in the form :

frjdh = (e1rjdh, e2rjdh,…, ekrjdh)

An impact category is made up of impacts of the same order of a climatic risk on e1, e2,…, ek respectively.

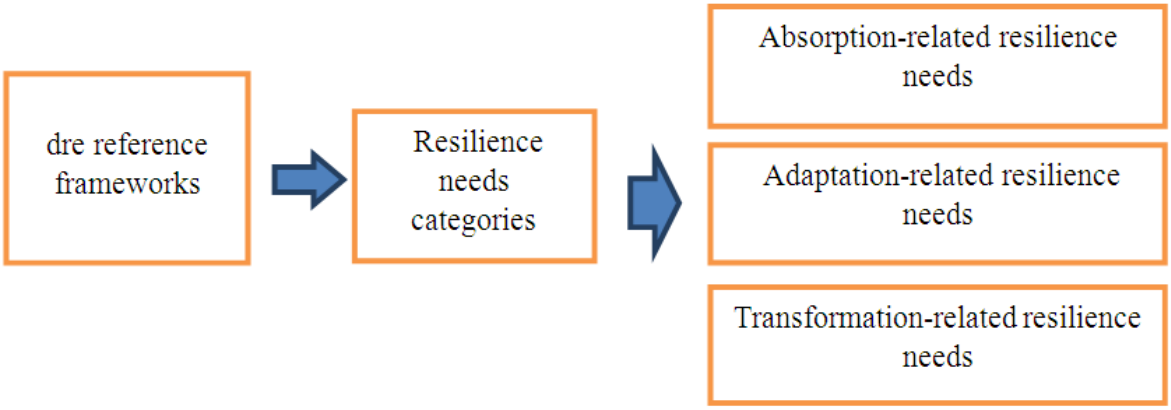
3) The third set of impact reference frameworks relates to specific impact reference frameworks.
For a risk rj, a specific impact reference framework drje includes the subset of the direct and indirect impacts of rj on the system S.
It is associated to the impact chains through :
drje = c1j u c2j u…..uckj
In this study, three impact reference frameworks can be developed :

- dr1e = c11uc21uc31uc41uc51
- dr2e = c12uc22uc32uc42uc52
- dr3e = c13uc23uc33uc43uc53

4) The fourth set of impact reference frameworks includes the global climate risk impact reference framework, dre. It is the sum of all the specific impact reference frameworks.
5) The fifth set of impact reference frameworks consists of socio-economic impact envelopes:

- dre_social = {*dre social type* }
- dre_environmental = {*dre environmental type elements* }
- dre_economic = {*dre economic type elements* }
- dre_institutional = {*dre institutional type elements* }
- dre_political = { *dre political type elements* }

In a practical way, dre reference framework impacts are used to develop categories of resilience needs, as illustrated through the diagram in Figure 3.



The vulnerability unit generates several sets of vulnerability factor frameworks to climate risks for the system under study.
The first set of vulnerability factor frameworks comprises vulnerability factor cells. A vulnerability factor cell vij refers to the subset of vulnerability factors to be addressed to mitigate the impacts under the impact chain cij.
The second set of vulnerability frameworks relates to vulnerability factor categories :
For a climate risk rj, a category of vulnerability factors vrjdh include the subset of factors to address in line with the category of frjdh impacts.
The third set of impact reference frameworks relates to specific vulnerability factor reference frameworks.
For a risk rj, a specific vulnerability factor reference framework vrje refer to the subset of vulnerability factors to be addressed in line with the impact reference framework drje.
The fourth set of vulnerability factor reference framework refers to the global vulnerability factor reference framework vre. It is the sum of all the specific vulnerability factor reference frameworks.
The fifth set of vulnerability factor reference framework consists of socio-economic vulnerability factors :

- vre_social = { *vre social type elements* }
- vre_environmental = {*vre environmental type elements* }
- vre_economic = {*vre economic type elements* }
- vre_ institutional = {*vre institutional type elements* }
- vre_ political = {*vre political type elements* }

The resilience unit develops several sets of resilience pathways for the system under study to climate risks.
The first set of resilience solution pathways comprises resilience solution cells:
A resilience solution cell zij is the subset of resilience solutions to address cell vij (vulnerability factors).
The second set of resilience pathways relates to resilience solution categories:
For a climate risk rj, a resilience solution category zrjdh refers to the subset of resilience solutions to address the vulnerability factor category vrjdh.

The third set of resilience pathways relates to specific resilience solution frameworks.
For a risk rj, a specific resilience solution framework zrje includes the subset of resilience solutions for vulnerability reduction under the vrje framework.
The fourth set of resilience pathways includes the global resilience solutions framework zre.
The fifth set of resilience pathways consists of socio-economic resilience envelopes :

- zre_social = {*zre social type elements*}
- zre_environmental = {*zre environmental type elements* }
- zre_economic = { *zre economic type elements* }
- vre_institutional = {*zre institutional type elements* }
- vre_political = {*zre political type elements* }

The figure below describes the overall approach considered for its implementation.

Overall approach of the study

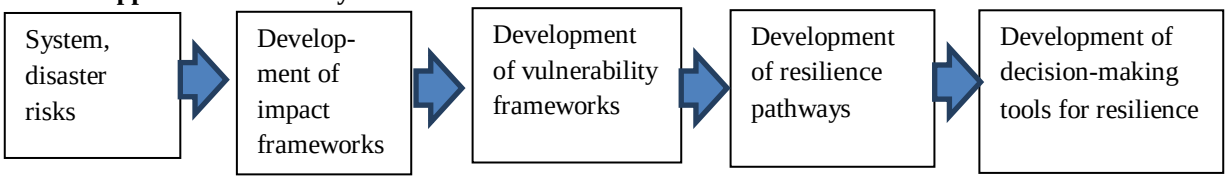


Figure 4: Climprospect's model global approach

3.2. Participatory Approach

In order to contextualize the proposed decision-making frameworks, interviews were conducted within sixteen (16) institutions, including major stakeholders involved in the food systems of Burkina Faso.

Such institutions include the ones involved in the production, processing, distribution, financing and international aid in Burkina Faso (state institutions, diplomatic representation, international organizations and civil society organizations).

Data was collected from stakeholders using interview guides, the content of which includes aspects of national production, state financing of food security and governance in the food security sector (institutions and mechanisms). In addition, it took into account significant and recurrent climate and disaster risks affecting the food security sector, the impacts of these risks, food security vulnerability factors and the resilience options to be promoted (Semdé et al.; 2020). Participants were selected on the basis of their involvement in the management of food security issues and their knowledge of climate change issues. According to the findings from the 5th IPCC report (IPCC, 2014), those with a prospective vision of the impacts of climate change on food security will have more relevant solutions to formulate. All the data collected from stakeholders was triangulated with the data mobilized in the literature review on the issue. This allowed us to better understand the views and needs of stakeholders regarding food security resilience to climate change.
Radar and Excel charts were used to process the data collected.

3.3. Nature of the data used

To conduct this research, two data types were considered. These include qualitative and quantitative data. They respectively relate to temperature, rainfall, food production systems, food security funding, food distribution systems and the conditions relating to food prices in the markets. The data were collected from studies conducted by the Ministries in charge of rural development in Burkina Faso and development agencies including research institutes.

IV. Results

This section focuses on results and is structured around three (03) essential points, namely impact reference frameworks, vulnerability frameworks and finally resilience pathways.

1. Impact reference frameworks

Impact reference frameworks of climate risks on food security will be analysed from the scientific references while taking into account stakeholders' views in the management of food security.
Scientific references include all the impacts of disaster risks on food security obtained from scientific analysis. They refer to ij sets representing the spectra of the direct and indirect impacts of climate risks on food security achieved in this analysis, the socio-economic impact spectra, stakeholders' views and the expressed resilience needs. It consists as follows:

1.1. Direct and indirect impact spectra

As demonstrated in (Semdé et al. ; 2021a), climate risk impacts such as drought on food security include direct impact spectra cij_direct and indirect impact spectra cij_indirect respectively representing potential drought risks on food security coverage in Burkina Faso. Direct impact spectrum refers to the field of droughts impacts experienced by all components of food security in the study area. These include:

dr1e _directs = { *the fall in national production, the increased degradation of the environment, the deterioration of the political climate, the deterioration of the nutritional qualities of food and the large demand from institutions in charge of food and nutritional security* } .

In Burkina Faso, such direct impacts in turn have environmental, social, economic, institutional and political consequences on the different components of food and nutritional security. Such consequences are called indirect impacts and consist of : dr1e_indirects = { *the fall in the supply of agricultural products, the fall in agricultural GDP, the fall in agricultural income, social conflict increase, the decline of the economy, the increase in the budget deficit, the increase in indebtedness, the increase in economic dependence, the slowing down of the economic and social development process, the failure to achieve socio-economic development objectives, increase in imports of agricultural products, increase in financing needs specific to agriculture, difficulties in accessing food products, weakening of national trade policies in place, distortion of food product markets , the multiplication of cyclical socioeconomic crises, the high prevalence of nutritional diseases, the large dependence on food aid, growth of consultation frameworks, ineffectiveness of the major stakeholders in charge of food and nutritional security and the inability of institutions to manage the food crisis* } .

The spectra described above shows that the impacts of droughts generate adverse changes on food and nutritional security in Burkina Faso, especially on all its components. As studied by the author (Semdé et al.; 2021 a), (dr1e) can be perceived as a tool measuring the pace and magnitude of droughts impacts on food and nutritional security coverage efforts, driven by policies and development initiatives in this sector in Burkina Faso. This situation was particularly developed through the existence of a correlation between climate profile and the annual agricultural production, namely the effects of severe drought recorded (1990, 1997, 2000 and 2004) on crop yields in Burkina Faso (CILSS, 2004 ; FAO, 2012 ; FAO, 2015). Specifically, it will consist in following the evolution of the dr1e set towards the empty set.

1.2. Socio-economic impact spectra

As demonstrated by some authors (Semdé et al. ; 2021a ; Badolo, 2015b; Gahi et al., 2015 ; Sanou et al, 2017), the impacts of climate risk such as drought on food security are also to be considered in the prism of socio-economic impact spectra. These include the socio-economic consequences of drought impacts on food and nutritional security identified in dr_1e set and classified through the socio-economic category. They refer to economic, social, environmental, institutional and political impact reference frameworks which can serve as benchmarks informing the development of response or recovery solutions to be included in development policies or initiatives in the food and nutrition security sector. In this paper, only economic and social spectra have been considered, given their importance in the context of Burkina Faso. These components include:

dr1_economic = { *the fall in agricultural GDP, the amplification of the market supply deficit in food agricultural products, the rise in the prices of agricultural products, the fall in the yield of rain-fed agriculture, the fall in agricultural income, increase in imports of agricultural products, increase in the budget deficit, increase in indebtedness, overall slowdown of economic activity, increase in economic dependence, disruption of public expenditure forecasts in the agricultural sector, the increasing financial needs specific to agriculture, the reduction of national economic investment capacities and the increase of poverty in agricultural households* } .

One of the main economic consequences in line with drought impacts include the low contribution of agriculture to the national economy.

dr1_social = { *inaccessibility to basic social services, disruption of social dynamics, loss of jobs, amplification of migration of rural populations, increase of household social charges, insecurity increase in rural households, the increase of nutritional diseases, the deterioration of the social climate, the increased dependence on humanitarian aid, the development of new dietary habits, the high prevalence of nutritional diseases and the deterioration of exchange conditions* } .

The fragility of the social fabric in the context of Burkina Faso requires social consequences caused by droughts on food security to be addressed in the first place. Dr1e_social expresses various social regression, changes in social demand and political disturbances of social actions.

1.3. Stakeholders' views

The whole dr1p is the spectrum of the direct and indirect drought impacts on food security as perceived by the major stakeholders in its management. Elements of this set include:

dr1p = {*decrease in agricultural yields, increased financial difficulties in accessing foodstuff, soaring food prices on supply markets, increased demand for food supply from Technical and Financial Partners (PTF), the loss of livelihoods by rural households, the difficulties of feeding poor populations and the increased mobilization of relief and emergency institutions* }.

In addition, the impacts demonstrate that the socio-economic issues generated by climate risks on food and nutritional security in Burkina Faso are likely to last despite the multiple dynamics undertaken while developing strategies (Palazzo et al. , 2016 ; Zougmoré et al. , 2016) . Such views corroborate the results obtained from scientific analysis.

2. Vulnerability frameworks

The selected climate and disaster risks have multiple and harmful direct and indirect effects on food security. As part of these studies, vulnerability frameworks are drawn up from both a scientific analysis and an analysis of local people's views. Those developed from scientific analysis include various types and are presented as follows:

As discussed in (Semdé and al. , 2021 b), vij spectrum refers to all the issues to be addressed to avoid impacts in the cell. Elements of vij1component include the set of vulnerability factors associated with cij1 impact, vij1 is the set of vulnerability factors associated with cij2 impact and so on. They are vulnerability factors to be addressed in order to reduce the influence of each of these climate risks on food security in the study area. Considering the vulnerability factors to be addressed to reduce the influence of drought on food security in Burkina Faso, data reveal four subsets, namely vij1 , vij2 , vij3 , vij4 and vij 5. Each of these refer to an envelope of vulnerability factors to be addressed in order to reduce the influence of drought on food security through its considered dimensions.

The whole vr1e represents the envelope of vulnerability factors to be addressed in order to reduce the influence of drought on food availability in Burkina Faso. Elements from vr1e include vulnerability elements that drought impacts reflect on the components of food security and their consequences. These include:

vr1e = { *rain-fed nature of agriculture; deficiencies in the diversification of the national economy with regard to increasing needs for social assistance in the event of drought ; deficiencies in the institutional leadership to strengthen the mechanisms for the prevention of the risks weakening national trade policies in place in a drought situation; deficiencies in economic investments for the creation of remunerative jobs considering increased migratory flows to neighbouring countries / mining sites in a drought situation; deficiencies in economic investments to secure road infrastructure in a drought situation; deficiencies in economic investments to secure existing nutrition habits considering the development of new habits in a drought situation; deficiencies in the economic investments of the transport sector in the face of the 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 participate in competition on the external market in drought situations; deficiencies in economic systems for controlling food prices in drought conditions; deficiencies in the economic resources made available to the Executive Secretariat for Food Security (SE / SA / MAAH) for food insecurity risk management in a drought situation ; deficiencies in the appropriate means for post-disaster response in the face of an increased consultation frameworks in the event of a drought ; deficiencies in public policies in connection with the consequent budget estimate for food security in the face of drought risks ; deficiencies in public policies in relation to the response to nutritional diseases in drought situations ; deficiencies in public policies for securing national food security institutions in the face of drought risks ; degraded state of agricultural land ; structural weakness of the social fabric ; inadequacies in the economic investments of mechanisms for the availability of agricultural products in a drought situation; inadequacies in economic investments to secure income-generating activities in the face of the degradation of the nutritional qualities of food in the event of drought ; inadequacies in economic investments to support income-generating activities in the face of the amplification of conflicts among stakeholders around natural resources in the event of drought; shortcomings in economic investments in the face of increasing financing needs specific to agriculture in a drought situation; shortcomings in economic investments to build highly resistant infrastructure to bad weather in drought situations; inadequacies in the mechanisms for the prevention and management of social conflicts in drought situations* }.

The whole vr1e shows that the vulnerability of food security in Burkina Faso due to recurrent droughts results from combined characteristics in this sector and in the economic, environmental, social, scientific, technological, institutional and political characteristics of the country.

According to (Semdé and al., 2021 b), decision-making tools for disaster risk prevention and management include four vulnerability categories, namely V1, V2, V3 and V4. Resilience solutions are to be developed basing on those categories. These categories are composed as follows: V1 vulnerability category for early warning, V2 vulnerability category relating to response, V3 vulnerability category for adapting capacities and V4 vulnerability category for the development of structural vulnerability management solutions.

3. Configuring food security resilience to risks and disasters

A resilience configuration is a state of a system protecting it from the impacts of a given climate risk. This study focuses on resilience configurations relating to impact categories according to the two approaches mentioned above, namely the scientific analysis and stakeholders' views. It also includes resilience configurations relating to impact categories and the means to avoid them.

For a better understanding of the context and an appropriate decision-making process, zr1e spectrum is divided into two subsets zr1e_system (composed of resilience solutions inherent in the system, r1 risk on food security) and zr1e_contextual (composed of resilience solutions linked to the context of the system, r1 risk of food security).

Zr1e _ System = { *Strategic plan for agricultural water development; economic mechanisms for securing income-generating activities to strengthen the State's endogenous investment capacities ; strategic plans for the economic strengthening of national response mechanisms ; mechanisms for matching institutional capacities and response needs ; revalorization of cereal banks and multiplication of local shops for food security stock management institutions (SONAGESS), agricultural development project / program under total water control* }.

Zr1e_Contextual = { *Establishment of subsidies on local production factors to make food products competitive ; instruments for improving the performance of economic investments by economic agents ; economic mechanisms for securing the people's income ; institutional instruments for increasing leadership in relation to resilience to food security; measurement benchmarks for balance between the impacts of the drought and the budgetary response measures from food security institutions ; institutional incentive instruments for access to microfinance by farmers for the security of economic activity ; institutional mechanism for integrating the effects of drought risks into development policies ; mechanisms for matching the capacities of institutions with the specific financing needs of the agricultural sector ; mechanisms for mobilizing funds for the rehabilitation and maintenance of road infrastructure ; mechanisms for securing economic investments in the transport sector ; innovative financing mechanisms for the restoration of degraded lands ; models of mechanisms for promoting social cohesion ; models of institutional mechanisms for the consequent integration of the effects of drought risks in recovery plans ; institutional models for promoting the culture of anticipation of the management of social conflicts ; tools for monitoring the inclusion of adequate solutions for securing and promoting national production ; strategic plans for the economic strengthening of national response mechanisms ; national market price control protocols for food products ; raising taxpayer awareness on the payment of taxes to build equity for sustainable socio-economic investment* }.

3.1. Resilience needs

Ideally, a food security resilience solution to droughts formulates as follows dr1e = Ø. To build such a configuration, Burkina Faso should put in place step-by-step solutions which include absorption-related, adaptation-related and transformation-related impact measures as decision-making tools.

Absorption measures reduce drought impacts on food security in the short term. The same applies to adaptation measures which bring about appropriate changes for a better management of drought impacts on food security in the medium term. Finally, in the context of Burkina Faso, transformation measures stand as benchmarks for developing and implementing long-term initiatives. These measures are presented as follow:

z_absorption (short term) = { *decrease in national production, infrastructure deterioration, increase in demand for food products, increase in transport costs, increase in intervention stocks, loss of crops, increased imports, strong accentuation of food aid to food security and increased food deficit* }.

z_adaptation (medium term) = { *increasing difficulties in setting up stocks, amplifying the contribution of imports to food security, reducing food rations in agricultural households, reducing food security stocks, the decline in national agricultural production yields, the decrease in agro-forestry production and the loss of agricultural resources for food security* }.

z_transformation (long term) = { *increasing difficulties in setting up stocks, strong accentuation of imports to food security, reducing food rations in agricultural households, reducing food security stocks, the decline in national agricultural production yields, reduced agro-forestry production and the loss of agricultural resources for food security* }.

V. Discussions

In this article, specifying a resilience pathway means establishing three reference frameworks of vulnerability factors. Such reference frameworks relate respectively to sets of short, medium and long-term vulnerability reduction objectives.

For the food security sector in Burkina Faso, the short-term vulnerability reduction objectives shall respectively include the improvement and reinforcement of policies relating to the development of wetlands and land security, to economic mechanisms for disaster response and recovery, emergency humanitarian assistance

mechanisms, access to early warning, transfer of new technologies for the regeneration of agricultural land and for water and soil conservation.

Medium term objectives shall include efforts leading to the establishment of a green fund for disaster risks, improved seeds, capacity building of agricultural producers in line with the use of various technologies, income diversification agricultural households, human and economic promotion of rural women. It shall also include the sensitization of agricultural producers to changes in behaviours, the revitalization of disaster risk management institutions at the local level and a better integration of climate and disaster risks into development strategies.

Long- term vulnerability reduction objectives suggest the development of new production technologies adapted to climate and environmental changes, the promotion of savings' culture, the reinforcement and support of community insurance companies, the intensification of functional literacy in rural areas and the implementation of early warning systems for flood and drought risks in rural areas. In addition, it shall consist in establishing a platform between agro-meteorological and agricultural extension services and producers, enhancing research for the development of short-cycle varieties more resistant to drought and the strengthening the mechanization of food production.

This situation requires food security management strategies to be rethought. To do so, one shall carefully take into account all the components of food security, in particular this component in the sector's resilience strategies (Lipper et al., 2014 ; Palazzo et al. , 2016).

While integrating the multidimensional nature of food and nutritional security and the successive consequences of major climate risk impacts in Burkina Faso, resilience solutions suggest an adjustment of approaches and practices in implementing responses. This is strongly emphasized in the research results of some authors (Yigo , 2011 ; Vonthron et al. , 2015). This approach would mainly consist in developing sets of resilience solutions associated with the identified impacts. In a practical way, resilience solutions should focus on reducing the impacts of these climatic hazards, adapting and preventing the effects of droughts, floods and high temperatures on food and nutritional security and the management of structural or fundamental causes of the sensitivity of food security to climate risks (Sanou et al., 2017 ; MERH, 2015).

Previous studies highlighted the adverse effects of the climate, especially droughts and extreme heat, on food and nutritional security in the Sahel, including Burkina Faso (IPCC, 2007; Roudier et al., 2011; Martin et al. , 2016). The main conclusions drawn from such studies include cereal deficits, the disruption of agricultural markets, the rise in the prices of agricultural commodities, the drying up of water points, the disappearance of grazing areas, the spread of malnutrition and socio-economic and political crises.

This paper integrates these results, and provide an in-depth analysis as it offers a better mapping of impacts and resilience needs through the concept of governance within food security institutions. This concept is actually the fifth component in the food security sector (Badolo , 2015 b ; Gahi et al., 2015 and Sanou et al., 2017).

Two aspects stress the theoretical contribution of this research. The first aspect includes the major dimensions of food and nutritional security considered in mapping the impacts. In the context of Burkina Faso, all dimensions or components of food and nutrition security are sensitive to climate risks. When one dimension of food security is not considered in the resilience process, the latter would transfer its sensitivity to other components. Therefore, a multidimensional approach to food and nutritional security appears to be an essential condition for an efficient and successful process in terms of vulnerability reduction. The decision-making framework is based on this logic behind the approach.

The second aspect relates to the impact index method. For a given risk and component of food and nutritional security, this method makes it possible to establish the exact extent of the impact. This results in a better assessment of the resilience needs of each component of food security to climate risk considered in its economic, social, environmental, technological, institutional and political dimension.

The results provided in this paper could be improved by associating scientific consultations on resilience pathways at the national level. Such an approach should pave the way for additional information and allow the results of this research to be further anchored in their context (Etwire et al. , 2017; Heijmans , 2013 ; Paris, 2015).

However, in Burkina Faso, no such consultation framework exists. Example should be taken from the international governance on climate change through the Intergovernmental Panel on Climate Change (IPCC), which is a forum for consultation around the results of the climate research. Implementing and hosting such a framework would therefore be useful.

VI. Conclusion

This paper aimed at establishing food security resilience pathways to the adverse effects of climate change in Burkina Faso. These resilience pathways resulted from impact and vulnerability reference frameworks of food security in the context of climate change in Burkina Faso

Climate change impacts on food security in Burkina Faso are complex. They are considered as direct and indirect impacts spectra which have consequences on the environmental, economic, social, institutional and political levels of these direct impacts. As a result, no component of food security is immune to the effects of climate change in Burkina Faso. These scientific results match with observations made on food security management at the national level. An in-depth analysis of the impacts makes it possible to identify the vulnerability factors and to map them into vulnerability categories in order to develop the most appropriate resilience solutions for a short, medium and long term implementation.

These policy adjustment pathways act as decision-making tools which can make a substantial contribution to the development and implementation of development policies and strategies. They contribute towards avoiding and preventing crisis in the agricultural sector and hence food security.

Policies should focus on improving the value chains that generate economic growth. With the view of diversifying agricultural production, the government must consider reducing the share of support allocated to the production of rice and cotton and include other products in sectional plans and strategies. Agricultural policies should not only consist in supporting producers through direct payments. These policies must rather strengthen the processing and routing initiatives in the country and regional markets. Finally, it is important to monitor the implementation of such policies.

A scientific approach requiring the development of resilience pathways as a solution is needed to reach food security and achieve the objectives of the National Plan for Economic and Social Development (NPESD) which stands as a national development pathway.

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