Rethinking Resilient Agriculture: From Climate-Smart Agriculture to Vulnerable-Smart Agriculture

Abstract

Climate-Smart Agriculture (CSA) is seeking to overcome the food security problem and develop rural livelihoods while minimizing negative impacts on the environment. However, when such synergies exist, the situation of small-scale farmers is often overlooked, and they are unable to implement new practices and technologies. Therefore, the main aim of this study is to improve CSA by adding the neglected but very important element “small-scale farmer”, and introduce Vulnerable-Smart Agriculture (VSA) as a complete version of CSA. VSA indicates, based on the results of this study, that none of the decisions made by policymakers can be realistic and functional as long as the voice of the farmers influenced by their decisions is not heard. Therefore, to identify different levels for possible interventions and develop VSA monitoring indicators, a new conceptual framework needs to be developed. This study proposed such a framework consisting of five elements: prediction of critical incidents by farmers, measuring the consequences of incidents, identifying farmers’ coping strategies, assessing farmers’ livelihood capital when facing an incident, and adapting to climate incidents. The primary focus of this study is on farmers’ learning and operational preparation to deal with tension and disasters at farm level. Understanding the implications of threats from climate change and the recognition of coping mechanisms will contribute to an increase in understanding sustainable management.

Keywords: Vulnerability; Sustainable livelihood; Food security; Climate change; Small-scale farming.

1. Introduction

Climate change affects agriculture by, for example, higher temperatures, more variable precipitation, and extreme climatic events including heat waves, floods, and droughts (Amaru, 2013). Agriculture is directly responsible for approximately 14% of the global greenhouse gases (GHG) emissions, and indirectly contributes to emissions through changes in land use, especially deforestation (i.e., agricultural expansion), which accounts for an additional 17% of the total GHG emissions (Seebauer, 2014). IPCC (2007) reports that developing countries account for approximately 70% of the agricultural climate change mitigation potential.

Sub-Saharan Africa is a region where rural households depend heavily on agriculture and where farming systems are highly sensitive to volatile climatic conditions (Rudi et al., 2012). By 2080, global agricultural productivity will decline by 3 to 16%. The loss in Africa could be even higher with 17 to 28% (FAO, 2011). Less developed countries continue to insist that significant reductions in GHG emissions are a precondition for the effectiveness of climate change adaptation initiatives (Rudi et al., 2012). African countries still desperately need to improve their agricultural production systems and tackle the threats of climate change and uncertainty, given the limited progress made within the United Nations Framework Convention (Ramirez et al., 2011). Given that agriculture is the leader in most low-income developing countries, the resilience of farming systems in adapting to climate change is crucial (Conant, 2009). Improvements in farm production systems also provide a major mitigation source by increasing carbon stocks in terrestrial systems and reducing emissions by increasing efficiency (Mahendra et al., 2011)

However, the maintenance and strengthening of food security mean that farm production systems need to adapt to increase productivity (Woolf et al., 2018) and, ultimately, lower output volatility in the face of important weather events (Azadi et al., 2011a). Production systems need to become more robust, i.e., better able to perform well in the face of vital stressful conditions and farming accidents, and to sustain farm and revenue. Greater production and resilience in agriculture require a transformation in natural resource management (such as soil, water, nutrients of land, and genetic resources). Moving to those systems could also lead, by increasing carbon sinks, to significant mitigation benefits and reduction in emissions per unit of agricultural product (Azadi et al., 2011b).

Climate-Smart Agriculture's (CSA) primary goal is modern agricultural technology and advances, such as inorganic fertilizers, pesticides, foodstuffs, food supplements, high yield varieties, land management, and irrigation techniques, leading to high yields and resilient systems (Mwongera et al., 2017). This was critical to fulfill an increasing population's food requirements and stimulate the economic growth required to alleviate poverty. According to a study by Mathews et al. (2018), in order to successfully and efficiently enhance the welfare of small-scale farmers in both short- and long-term initiatives, it is necessary to understand the costs and benefits of potential CSA options. Hellin and Fisher's (2019) study showed that, as part of climate change adaptation and mitigation activities, agricultural researchers have developed a variety of agricultural technologies and methods, collectively known as CSA.

Ineffective CSA targeting thus lacks the distinct livelihood transition capacities of small-scale farming families, which are related to the possibilities and constraints afforded by various livelihood paths, both agricultural and non-agricultural. Climate-smart approaches would also entail a wider and more ambitious agenda, including funding for the capacity of farm households to create livelihoods that are not dependent on agriculture. Studies by Sarkar et al. (2019) also indicate that the notion of CSA has arisen as a solution that can lead to improved agricultural productivity and poor household incomes in the face of global environmental change. In order to achieve global food and nutritional stability, this paper discusses the suitability of implementing CSA activities to support sustainable agriculture. It also discusses the connections between the CSA (productivity, adaptation, and mitigation) components and their commitment to achieving the objective of sustainable agricultural production. Despite the ability of CSA to achieve sustainable agriculture, there are weak relations between the field-level components of CSA. More significantly, the principle is often poorly grasped by different stakeholder levels.

In a study by Totin et al. (2018), they expressed that although three pillars (productivity, adaptation, and mitigation) are included in the CSA definition, the literature has hardly discussed them in an integrated manner. It also seems that the construction status of the study sites determines which pillars are supported. The building status of research sites also appears to decide which pillars are funded. The CSA literature has had a gradual focus on structural issues (Mazhar et al., 2020). It has concentrated primarily on the architecture of information, business structure, and complicated institutional environments (Parente et al., 2019). Less attention has been paid to understanding investments in physical infrastructure and the engagement of actors, or how the implementation of CSA alternatives will affect the historical, political, and social context. Rethinking CSA approach will create potential avenues for scaling of CSA alternatives by combining application packages and structural supporting conditions (Mazhar et al., 2020).

Vulnerable-Smart Agriculture (VSA) starts with small-scale farmers and aims to understand the barriers they face in improving their livelihoods, followed by the “participatory” design of intervention programs that help farmers with overcoming these barriers. Yet, CSA in lower income countries is not capable of recognizing the poverty and reflecting the lack of capabilities and assets and fails to move out of poverty (Mathews et al., 2018). Accordingly, the main assumption of VSA is that approaching sustainable livelihoods is the main pre-requisite for increasing food production, adapting to climate change, and mitigating GHG emissions (Kanamaru and Fujisawa, 2018).

Hence, VSA can be considered as an improved tool within the context of changes in climate. Thus, for all stakeholders, it is necessary to design region-appropriate VSA strategies using available assets (Kanamaru and Fujisawa, 2018). This includes material assets for productive activities such as land access, other natural resources, financial and credit capital, tools, and inputs. It also represents human capacity (family expertise and skills) and social and political influences, such as the ability to negotiate equal and sufficient outcomes in the market chains where people buy and sell goods and services (IISD, 2011).

Climate change also has a major impact on livelihoods, particularly the livelihoods that are primarily oriented towards natural resources (Vincent et al., 2017). Crop production, livestock production, and fishery are largely affected by changing climate. Climate change can also minimize the opportunities for new livelihoods. For example, the damage of physical capital (such as infrastructure) due to frequent natural disasters could limit the opportunity of agro-ecological tourism, which could work as an additional sustainable livelihood opportunity for the poor rural people (Singh et al., 2017). Around the world, small-scale farmers play a significant role in agricultural production (Ajayi and Catacutan, 2012). However, they are considered as marginalized and socially excluded rural communities and the majority of them are suffering from poverty and food insecurity (Oxfam, 2014). Simply put, the CSA assumptions and objectives need to be adjusted to VSA that not only mitigates the changes in climate and addresses food security but also places small-scale farmers and their livelihoods at the heart of any agricultural activity. As a result, the system can be smart enough to be resilient to climate change and assure a sustainable livelihood for these farmers. Climate risk management options affecting the transition of both agricultural and non-agricultural livelihoods by means of livelihoods would involve concerted cross-disciplinary research and development spanning a larger variety of disciplines than have been the case so far in the framework of CSA to VSA. It is also important to disseminate CSA and VSA methods at field level in order to create a better future by using them in university syllabuses, conferences, symposiums, and analyses. The consequences of not knowing and using these strategies on the economy, environment, and society will also be assessed. For this purpose, literature, definitions, and differences regarding the framework of sustainable livelihood, CSA, and VSA have been studied.

Accordingly, the main aim of this study is to improve CSA by adding the neglected but very important element "small-scale farmer", and introduce VSA as a complete version of CSA. Appreciating small-scale farmers as the heart of a resilient agricultural system, this paper proposes major changes needed in the CSA set-up by building up a conceptual framework at a farmer level.

2. Theoretical background and literature review

2.1. Climate-smart agriculture

Farmers have changed their agricultural practices to adapt to changing climate conditions and other challenges, particularly in developing countries (Nyasimi et al., 2017). Agricultural practices are changing to target both livestock and crop productions, including improved fodder production, using new crop varieties and animal breeds, water conservation technologies and soil and land management practices (Sattar et al., 2017). In resource-poor small-scale farming systems, these technologies (referred to as CSA technologies) and practices are anticipated to enhance adaptive capacity, food security, and make a contribution to climate change mitigation (Hellin and Fisher, 2019). Implementing CSA practices and technologies individually or in combination can significantly reduce the negative impact of climatic variability on agriculture (Ali and Erenstein, 2017).

CSA is also defined as a modern agricultural system which is capable of: i) increasing yields, ii) dealing with climatic extremes, and iii) contributing to climate change solutions (Table 1). CSA systems are designed to optimize the use of inputs and effective management practices after harvest (Chandra et al., 2018). With an emphasis on modern agricultural techniques, CSA is a system that aims to increase productivity, adaptability, and, conversely, reduces (mitigates) GHG emissions (World Bank, 2011). Furthermore, CSA differs from "business-as-usual" approaches in that it helps to strengthen the coordination of activities by farmers, researchers, the private sector, civil society, and policymakers to improve farmers' adaptive capacity as well as agricultural production system adaption and resource use efficiency (Lipper et al., 2014). When it comes to the three pillars of CSA, adaptation and food security are widely seen as apparent goals for agricultural development in the face of climate change (Rosenstock et al., 2016). Some critics, however, have questioned the rationale for CSA mitigation targets for small-scale farmers, prompting more in-depth discussions about mitigation's role within a broader CSA approach (Lipper et al., 2014).

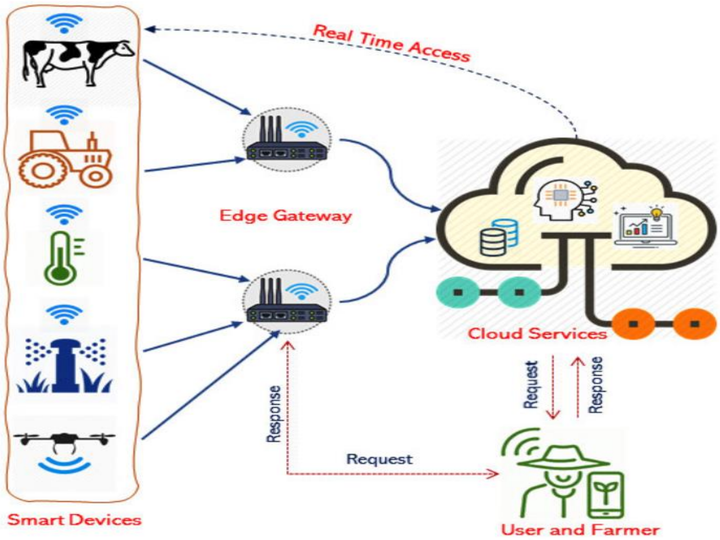

Fig. 1. A model of end-to-end engagement in smart farming between different stakeholders.

Source: Gupta et al. (2020)

Fig. 1 suggests an end-to-end relationship with different individuals engaged in the environment of smart farming. In the sector, physical sensors and livestock produce data and receive command operations from user apps. In terms of security and data privacy, these on-farm devices are linked to gateway-supported edge nodes that allow connectivity between in-farm devices, filtering sensor data, and real-time agronomy analytics.

Extensive studies on stable devices used in intelligent agriculture, such as drones currently available for field spraying, may help expand the smart agricultural ecosystem and combat climate change. However, research on these innovations is done much of the time without taking into account the environment in which they are used. The complex, smart farming ecosystem has specific aspects that are affected by environmental factors, such as farm machinery, labor sharing, and organizational decisions. Domain-specific issues like location, user ability set, insider attacks, and generated data necessitate smart farming-specific protection mechanisms. As a result, more research is needed before smart farm technology is widely accepted in the community (Gupta et al., 2020).

2.2. Vulnerable-smart agriculture

VSA is defined as a resilient system that puts small-scale farming at the heart of any intervention program. VSA is considered to be a smart system because it has the potential to i) predict critical (climate and farming) incidents in agriculture, ii) measure the consequences of these incidents, iii) assess farmers' livelihood assets, and iv) identify their coping strategies to face such incidents. The ultimate goal of VSA is to empower small-scale farmers in such a way that they can raise their voice and actively contribute, not only to climate change mitigation but also to other critical farming incidents that may cause significant yield loss in agricultural production and food security.

Indeed, CSA practices at the national level are associated with a number of issues that, if not addressed properly, have the potential to undermine the legitimacy and quality of decisions made. First and foremost, relevant stakeholder groups should contribute to expert knowledge and decision-making (Brandt et al., 2017). Second, the large number of criteria that must be considered when selecting and prioritizing CSA practices in specific locations can lead to a great deal of complexity and uncertainty (Greene et al., 2011). Third, reliable quantitative and spatially explicit data are required to identify regions suitable for targeting specific CSA practices (FAO, 2013). For example, the database should include social, economic and biophysical determinants of small-scale farmers' agricultural vulnerability to climate change, allowing for a demand-based approach like VSA (Fellmann, 2012). There is a need for a framework that incorporates information and opinions from a wide variety of expert stakeholders, and evaluates those views with spatially explicit datasets on vulnerability practices to support robust decision-making on CSA outcomes (Brandt et al., 2017).

In this context, VSA is proposed to be an effective extension of CSA that addresses climate change and food security by integrating adaptation and mitigation measures at farmer level. Its goal is to reduce small-scale farmers' vulnerability to climate change by improving agricultural systems' adaptive capacity to climate stress and, as a result, ensuring food security while lowering GHG emissions from climate-changing agricultural practices and land uses (Campbell et al., 2014). As a result, as a complement to CSA, the VSA concept includes both a short-term (adaptation) and long-term (mitigation) insight, which should be taken into consideration in proper planning processes for small-scale farmers.

A demand-based perspective, as proposed by VSA, should be adopted by explicitly incorporating the vulnerability concept into CSA, implying that regions more vulnerable to climate change needs more urgent interventions to enhance their adaptive capacity (Abson et al., 2012). As a result, information about relevant social (e.g., education), economic (e.g., market access) and biophysical (e.g., climate) dimensions should be considered when determining where specific VSA practices are appropriate. Table 1 shows the main components of CSA and VSA as discussed above.

Table 1
The main components of CSA and VSA

Approach	**Components/references**				
	Productivity	**Mitigation**	**Adaptation**	**Services to farmers**	**Land management options**
CSA	Increases yields as a modern agricultural system.	Addresses the climate change impacts (GHG emission reduction) mainly at large and/or global scale.	Optimizes the use of inputs through modern technologies.	Seeks changes in policymakers' agenda based on increased yields.	Provides sustainable soil and land management for increased crop productivity.

	Amin et al. (2015)	FAO (2017)	Makate et al. (2016)	Steenwerth et al. (2014)	Mwongera et al. (2017)
VSA	Puts small-scale farming at the heart of any intervention programs as a resilient agriculture system.	Measures the consequences of climate change incidents; reduces GHG emissions from agricultural practices and land uses that contribute to climate change at farm level.	Identifies small-scale farmers' coping strategies and provides them with resilient farming system alternatives.	Believes only when small-scale farmers are active in formulating and regulating the agenda, the substantial changes can be made.	Focuses on socio-cultural properties of small-scale farmers dealing with crop yields and land management practices.
	Abegunde et al. (2019)	Hussain et al. (2020)	Fadina and Barjolle (2018)	FAO (2017)	Yengoh (2012)

CSA is supposed to achieve the three dimensions of sustainable development (economic, social, and environmental) by acknowledging food security and climate challenges in agricultural development through the development of technical, policy, and investment conditions (FAO, 2013). CSA practices do not have to be novel; in fact, any agricultural method or technique that leads to the effectiveness of the three pillars can be considered climate-smart. The various CSA techniques frequently differ significantly across the components, and as a result, they must be coupled as part of the overall approach to enhance the effectiveness (FAO, 2017).

VSA is an extension of CSA due to the feedback linked to the short-term planning in small-scale agriculture. Furthermore, because VSA provides a fast and direct return on investment, it is more likely to motivate individual producers (Thornton and Comberti, 2013). VSA, on the one hand, can produce complementarities in mitigation and on the other hand, it can result in synergistic co-benefits. As a result, small-scale farmers can play a role in climate change mitigation, as evidenced by farm-level implementation of agroforestry or crop-livestock systems (Rakotovao et al., 2017). In fact, adaptation frequently occurs at the local level and serves as an entry point to address the direct needs of small-scale farmers, who are incorporated in a variety of social networks that connect both institutions and individuals. Martinez-Baron et al. (2018) argued that small-scale farmers' contributions to climate change adaptation and mitigation are required through the application of copying strategies. Small-scale farmers could become more resilient to climate change in the future by adopting low-carbon adaptations, thereby contributing to global mitigation efforts. However, most small-scale farmers will need to implement VSA options widely and quickly in order to achieve this. When designing and implementing VSA at a national scale, explicit recognition of how social capital and networks operate in relation to climate challenges has the potential to be a critical ingredient. As such, it can be concluded that VSA as an extension of CSA can be used as a feasible tool to reduce GHG emissions from agricultural practices.

2.3. Research gap

Agricultural practitioners must invest in research and development of technologies and good practices in order to implement and scale up CSA. The role of public finance in providing the necessary support and incentives for farmers to make necessary investments is also critical. As a result, farmers should be regarded as the most important source of human capital (FAO, 2013). Several studies (e.g., Long et al., 2019) showed that a trade-off between maximizing agricultural production and environmental protection is unavoidable. In the long-term, the cost of undermining natural assets cannot lead to sustainable farm production (IFAD, 2012). However, small-scale farmers, who are operating near or below the poverty line might not always have the assets and encouragement to prioritize sustainable approaches due to lack of necessary government supports (IFAD, 2012). Social and environmental systems are critical if communities, particularly in the developing countries, are adapted to future challenges (Adger et al., 2003). While climate change adaptation and adaptive capacity building are promoted as essentials to sustainable agriculture, as long as small-scale farmers' sustainable livelihoods are neglected, all of such capacity building will be at risk (Jamshidi et al., 2020). In fact, climate change adaptation strategies should address the complex situation of small-scale farmers, who are the most vulnerable group to the effects of climate change (Commission for Africa, 2005).

In order to minimize the vulnerability of small-scale farmers, such adaptation strategies require a system that is sensitive and proactive to climate change consequences.

In the current study, the main attempt is to review different components of CSA to develop a VSA conceptual framework in order to better understand the need for trade-offs and synergies between the three pillars of CSA. We argue that, because the buzzword CSA is solely focused on climate change, the concept of VSA is a more comprehensive term and more effective effort because it resonates with and highlights the role of small-scale farmers. This study therefore underlines that a more farmers-friendly of the climate smartness of agricultural production systems will require a completed version of CSA concept -called VSA.

A review on the CSA literature shows that despite many studies that have been conducted on CSA, low-income poor countries with small-scale subsistence farmers have not yet been able to move out of poverty and improve the livelihoods of these farmers. More importantly, very few studies on CSA seek to increase participatory-rural projects and improve small-scale farmers' livelihoods in rural areas. As a result, despite previous studies (e.g., Andrieu et al., 2019), there is still a research gap on current and future rural living conditions that must be addressed by CSA interventions in order to enhance small-scale farming opportunities (e.g., benefit of timely yields). To fill this gap and to identify different levels of possible interventions, as well as the development of VSA elements, this study contributes to designing a conceptual framework which consists of the five main elements: i) predicting and responding to climate incidents, ii) measuring the consequences, iii) identifying small-scale farmers' coping strategies, iv) assessing small-scale farmers' livelihood capitals, and) adapting to climate change incidents.

3. Conceptual framework

Today, the literature is continuing to grow on collaborative procedures designed to support climate change policy planning, with certain strategies specifically aimed at supporting CSA nationally or locally (Mwongera et al., 2016). There are not, however, several methodological methods for modeling VSA structures with an explicit focus on vulnerable small-scale farmers. In order to design a comprehensive and effective VSA conceptual framework, it is necessary to identify small-scale farmers' livelihood capital and their coping strategies to climate incidents. Accordingly, this paper proposes a conceptual framework (Fig. 2) that will enable a holistic perspective of various factors that together explain how small-scale farmers can most effectively face climate change incidents. Climate vulnerability is a diverse and nuanced policy issue that interacts with global, regional, national, local, social, political, economic, and ecological variables (Rahman and Hickey, 2020). Consequently, the understanding of climate risk varies from sector to context (Jurgilevich et al., 2017). Despite the complex nature of climate vulnerability, governments and communities are taking steps to promote climate adaptation, defined by the IPCC as the phase of adaptation to and impacts of real or anticipated climate (IPCC, 2014). The Fifth Assessment Report of the IPCC Working Group II stated that different regions respond to the consequences of climate change in various ways by climate-sensitive decision-making (Rahman and Hickey, 2020). This reflects the increasing awareness in different contexts of climate uncertainty, the types of tools required for various actions, and socio-political complexities.

Extreme poverty, social discrimination, and a strong dependency on natural resources also define the livelihoods in rural areas of the developed countries. Natural resource-dependent and environment-sensitive subsistence practices may become particularly at risk in the face of climate change-related stresses. This scenario poses two main science and policy challenges: first, local resource usage and delivery patterns (Adger et al., 2006), and second, the degree of ambiguity regarding livelihoods related to climate variability (Rahman and Hickey, 2020). When environmental effects on geographically relevant socio-economic and social-ecological environments are analyzed together, each of these large issues can be better understood (Cohen et al., 2016). However, the awareness of various circumstances in a given region is likely to vary with political agendas, widely noticeable climate effects (e.g., extreme loss of life and property), and media attention (IPCC, 2014).

It has been suggested that climate change and its pressures would both limit the potential of a state to offer jobs and resources for people affected, cutting the capacity of rural communities to adapt to the impacts of climate change (Rahman and Hickey, 2020). Furthermore, lack of awareness and information flows will contribute to an unequal allocation of scarce resources leading to conflict and social insecurity (Grasso et al., 2014). In emerging areas where expertise and technology have not yet been adequately established, this possible situation is especially important (Rahman and Hickey, 2020).

Small-scale climate change adaptation decisions for farmers demonstrate that numerous stressors accelerate adaptation (Burnham and Ma, 2016). Small-scale farmers' climate change adaptation decisions indicate that adaptation is motivated by several stressors. Decisions on climate change adaptation rely on the views of adopters and qualitative factors such as community, schooling, ethnicity, age, capital, and structural variables (Prager and Posthumus, 2010).

Previous research on small-scale farm capability suggests that adaptive capacity components can be considered as deciding factors (Burnham and Ma, 2017). Small-scale agricultural systems now provide hundreds of millions of the poorest households worldwide with livelihoods and food. These processes are being changed by both climate change and the strategies designed to respond to it. With potentially significant consequences for economic growth, human wellbeing, stability, natural resource conservation, protection, and eventually the achievement of the Sustainable Development Goals, these impacts can be expected to continue and escalate SDGs. Other stressors, including infectious diseases, nutritional shortages, natural resource depletion, and unstable land tenure, could interact with the development risks presented by climate shocks to compound risks to small-scale livelihoods. At the same time, there are countless adaptation capacities for small-scale farmers, including awareness, networks, and management processes that have long made it possible for small-scale systems to deal with environmental and socio-economic change in a changing world.

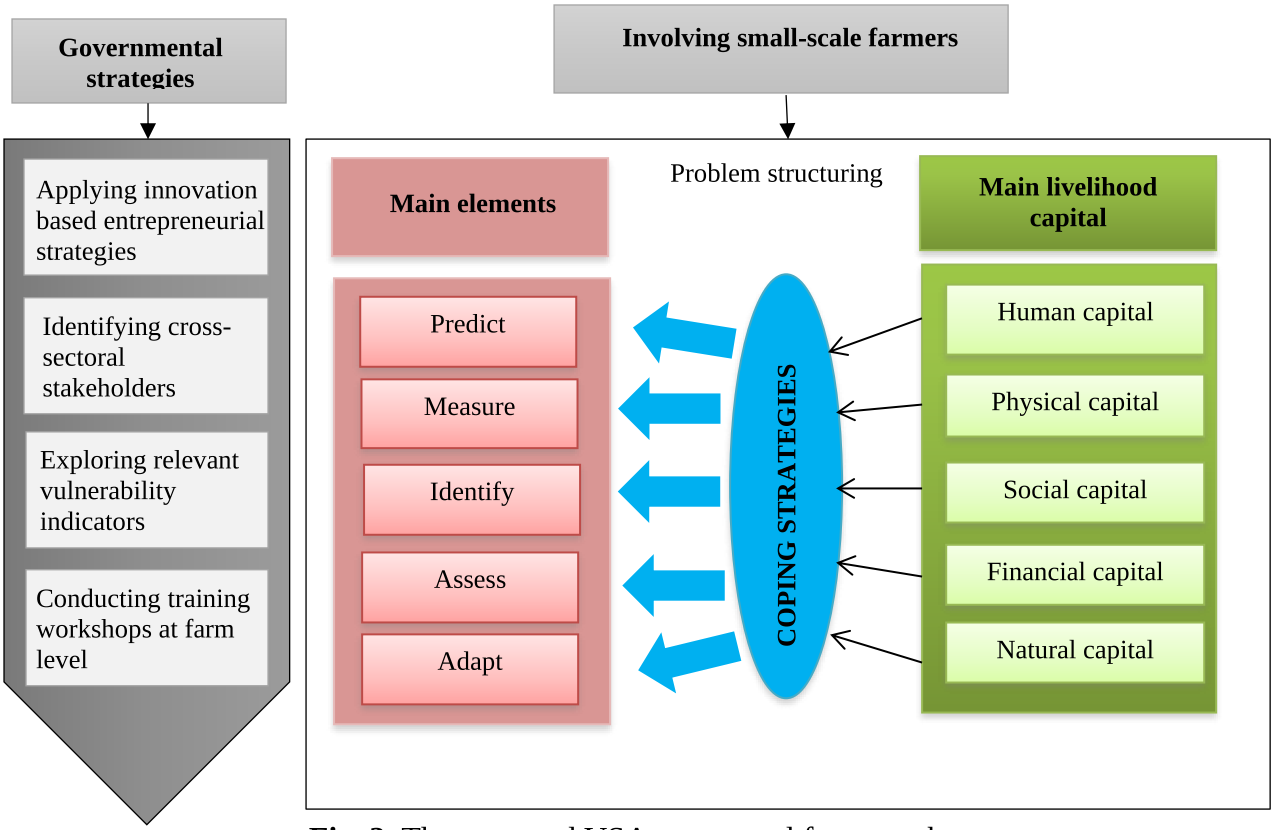

Fig. 2. The proposed VSA conceptual framework.

In general, the evaluation of livelihood vulnerability considers human and ecological environments as two intertwined systems (Rahman and Hickey, 2020) and considers vulnerability to be the product of not just evolving climate properties but also of social, economic, structural, political, environmental, and technical processes (Debortoli et al., 2017). Focusing on a household's ability to predict and react to the impacts of climate change, the CSA and VSA strategies suggest that inadequate storage of assets (at present) restricts a household's ability to respond to future climate impacts (Sitaula et al., 2020). VSA as a resilient system puts small-scale farming at the heart of any intervention program, predicts critical (climate and farming) incidents in agriculture, measures the consequences of these incidents, assesses farmers' livelihood assets, and identifies their coping strategies to face such incidents (Boon et al., 2012). This system helps empower small-scale farmers and seeks a solution with poor farmers, not only to climate change mitigation but also to other critical farming incidents that may cause significant yield loss in agricultural production and food security. VSA strongly assumes that only when farmers are active in formulating and regulating the agenda, the substantial changes could be made (Debortoli et al., 2017).

Climate change brings both social and natural capital processes uncertain and dramatic changes, and its effects are adversely felt as it reduces the ability of a household to expand and evolve (Zougmoré et al., 2016). The insecurity of households relies on the existence of properties over which a household has complete access. Assets buffer danger, boost recovery, and produce unequal results for households in a group depending on the degree of ownership (Islam and Hyakumura, 2019). Poorer areas of society are more likely to slip into poverty pits because of frequent incidents of climate stress that restrict their ability to preserve livelihoods, rendering them the worst victims of climate change (Etzold and Mallick, 2016).

In particular, access and right to assets are regulated by structural mechanisms that go beyond those of the national government and its legislative frameworks; therefore, wealth allocation is closely related to social structures and local political regimes (Okediji, 2019). In a socially and economically segregated country, because of their lack of social networks and low political influence, disadvantaged people tend to have minimal levels of involvement in both local and national institutional structures (Okediji, 2019). Therefore, it is also argued that minimizing vulnerability can be improved by maintaining social justice for disadvantaged communities and their economic integration (Siders, 2019). Vulnerability thus highlights the importance of deliberative policy-making that supports and encourages citizen engagement in the creation of CSA and VSA driven adaptation strategies. (Mersha and van Laerhoven, 2019).

Vulnerability is defined as negative (and sometimes positive) impacts on poor people’s capitals and livelihood choices (Jome Poor and Kioomars, 2012). Vulnerability has two aspects: external factors include shocks, seasonality, and trends, and internal factors associated with carelessness are instigated by inability and incompetence to deal with these factors (Asian Development Bank, 2017). Shocks such as droughts, cold and frosts, storms, floods, soil salinity, pests, and diseases (Asian Development Bank, 2017) can directly destroy individuals' capital and cause people to abandon their homes and properties (such as land) as coping strategies when damage to the poor is pronounced (Asian Development Bank, 2017). Trends include population changes, environmental changes, government and governance, economics, and technology (Asian Development Bank, 2017). When they are predictable, such trends may (or may not) be safe, but they have particular impacts on the economic return rate and the choice of adaptation strategies. In the context of sustainable livelihoods, small-scale farmers have different access to livelihood capitals, and the goal is to extend their well-being. The types of capital that small-scale farmers need for their livelihood choices and coping strategies’ development to face climate change incidents (Asian Development Bank, 2017) are as follows:

Human capital: This capital reflects knowledge and skills, job potential, adaptive capacity (Asian Development Bank, 2017), and health, which enable farmers to follow and achieve their livelihood goals. In addition, at the household level, there is a factor in the quantity and quality of available labor that varies according to household size, ability level, leadership capacity, and health status. Furthermore, human capital development facilitates the transition to more sustainable and climate-smart agricultural productivity.

Physical capital: The basic resources and commodities needed to sustain farmers’ livelihoods include physical material. The infrastructure includes physical condition improvements that help individuals fulfill their basic needs and make them more efficient. More specifically, physical capital includes farm buildings and different types of facilities and equipment used in agricultural production that help farmers measure the expected profits and/or the extent of climate change incident (Brandt et al., 2017)

Social capital: Social capital refers to networks and unions, social tools gained by individuals to achieve their livelihood goals (Asian Development Bank, 2017). Social capital can improve the individual confidence and capacity to work together and extend their access to larger structures, such as political or civil institutions, that are inclusive. Social capital brings about membership in more formal groups, often requiring compliance with laws, norms, and penalties by mutual agreement. Mutual confidence and transactions that promote collaboration and reduce transaction costs will provide an informal framework for poor people's protection.

Financial capital: This capital refers to the supply of funds and financial services that cause various adaptation strategies to be followed by farmers and involves two primary sources: (1) cash, bank deposits, or cashable properties, such as livestock and jewels, that are available commodities; lack of associated debt; and independence from third parties, and (2) regular cash inflows, including income from work, retirements, or other official transfers and remittance that are highly dependent and reliable (Campbell et al., 2014).

Natural capital: Natural capital signifies resources such as land and production resources, water resources, animals, habitats, natural products and plants, and environmental facilities (Asian Development Bank, 2017) in terms of how these resources and services are used for people’s livelihood. Natural cycles and events that damage natural resources (such as forest fires, flooding, and earthquakes that devastate farmland) are many of the shocks derived by the seasonal changes in the valuation of natural capital.

Therefore, considering the main capital of a sustainable livelihood framework, the VSA conceptual framework has been developed in this study. The analytical basis for the implementation of VSA consists of five elements as described below:

⇒ **Elements 1**: tries to understand how small-scale farmers *predict* climate change incidents. This mainly focuses on understanding the thoughts and perceptions of small-scale farmers about the incidents and their predictive tools and indicators. Therefore, the main coping strategy that could be practiced by farmers is to predict the up-coming climate change incidents through modern technologies such as early-warning systems.

⇒ **Element 2**: seeks to understand how the impact of incidents is *measured* by small-scale farmers. It aims to ask them about the various consequences of an incident. Taking into account the dimensions of sustainability, this element emphasizes on the social, economic, and environmental impacts of an incident. Understanding the extent of incident is a major step to cope with it. Therefore, by an accurate measurement, we can mitigate climate change effects on small-scale farmers' livelihoods.

⇒ **Element 3**: tries to understand how small-scale farmers *identify* their coping strategies. Small-scale farmers are using various coping strategies to address the vulnerable incident situation. Choosing the best coping strategy based on the extent of an incident and available financial capital is of high importance. By doing so, despite the constraints hindering small-scale farmers, they will be able to develop both indigenous and modern coping strategies to reduce the effects of climate change on their source of livelihoods.

⇒ **Element 4**: addresses how small-scale farmers *assess* their livelihood capital when facing an incident. Taking into account the small-scale farmers' sustainable livelihood capitals, this element focuses on addressing their livelihood's requirements in the event of incidents. The coping strategy here is to target both the extension agent and the advisory services that enhance complementing the use of indigenous and modern coping strategies.

⇒ **Element 5**: ultimately discovers how the farmers can *adapt* to climate change incidents using resilient farming system by focusing on the contribution of natural capital such as land and production resources, water resources, animals, etc. The coping strategy here is to practice resilient farming system to implement appropriate interventions.

In order to review different conceptual formwork in similar previous studies, Ouedraogo et al. (2018) examined the experiences and lessons learned in Senegal where different climate information services have been implemented using participatory approaches (field presentations, stakeholder meetings, training workshop interviews, etc.) in order to actively engage manufacturers, technicians, politicians, and goods. Andrieu et al. (2019) in another study present a methodological framework to co-design CSA systems with local stakeholders (farmers, scientists, and NGOs) in order to achieve major changes. Seven stages of the CSA's co-design process were used, and for each stage, different methods and methodologies were applied, including the evaluation of focus groups, social network research, growth cycle evaluation, and on-farm experiments.

5. Discussion

5.1. The main features of designing VSA systems

This section draws on our research to help strengthen the theoretical basis of future resilience tools and frameworks to evaluate agricultural systems (especially small-scale agriculture) vulnerability and resilience. As stated above, there is a need to rethink the existing CSA assumptions and objectives and move towards a VSA that seeks to address food security and climate change, define all vulnerable aspects of small-scale farming, and underline the role of small-scale farmers and their livelihoods in all farming activities. VSA begins with small-scale farmers attempting to understand the obstacles they face in promoting their livelihoods.

This action is followed by (participatory) designing those intervention programs that farmers can most adapt to overcome these obstacles. Based on the findings of this study, VSA demonstrates that none of the decisions made by policymakers can be realistic and functional as long as the voice of the farmers influenced by their decisions is not heard. Therefore, this study proposed a framework consisting of five elements: *predicting* critical incidents by farmers, *measuring* the consequences of incidents, *identifying* farmers' coping strategies, *assessing* farmers' livelihood assets when facing an incident, and *adapting* to climate incidents.

Depending on the availability of know-how on designing a system (Meynard et al., 2012), the adaptive or disruptive features of these systems, and the presence and utilization of farmers' modeling methods, there are different approaches to design innovative agricultural systems. In this analysis, the philosophical structure is intended to discuss the coherence of the CSA systems design process. Such coherence lies primarily in the need to acknowledge the five key elements of the VSA conceptual framework suggested by this study. Such acknowledgment may occur at the stage of the farm when prioritizing the practice of the CSA system (Torquebiau et al., 2018). Particularly in our study, we indicated that VSA strongly believes that significant changes can be made only if farmers are actively involved in the design and regulation of the agenda. Thus, incorporating agricultural programs to the natural hazards' mitigation programs, along with index drought insurance, will maximize the resilience of farmers to financial impacts related to climate change to provide long-term farming and community safety to support VSA. Therefore, by developing information strategies, the reduction of farmers' uncertainty about their impact on climate change helps design robust risk management policies and limits excessive financial costs (Antón et al., 2013).

5.2. Farmers' decision-making towards the adoption of CSA practices

The results obtained indicate how well innovation models are applied to all climate behaviors, in particular, given the fact that national and international governance regimes have a significant impact on the actions of farmers (Reed et al., 2013). The spread of the innovation model can provide critical insight into decision-making. This model follows a succession of steps: knowledge, convincing, decision-making, implementation, and validation (Arbuckle et al., 2013). In this model, innovation is adopted; farmers are communicated with extension agents' innovations generated by agricultural research. It can emphasize too much traditional socio-economic variables and ignore the implications that other social factors (e.g., networks, gender, social standards, values, and attitudes to climate change) and uncertainty may have on the practices that are ostensibly compatible with CSA priorities (e.g., new cultivars and farm crops or changes in N fertilization) (Vervoort et al., 2014).

This study has shown that effective outreach strategies will provide farmers with a better understanding of their climate change perceptions and willingness to respond through mitigation and adaptation. We know little about the willingness of the farmers and their advisers to use tools, their data on climate change, or their capacity in the existing decision-making processes to incorporate this knowledge (Khatri-Chhetri et al., 2017). Consequently, farmers who consider that climate change takes place mainly due to human activity are more likely to support both mitigation and adaptation steps.

5.3. Strengths and limitation of the suggested conceptual framework

This study attempts to address major changes needed in the CSA concept by designing a conceptual framework for VSA at the farm level. The main goal of this study is to improve CSA by adding the neglected but very important element "small-scale farmer", and to introduce VSA as an extension of CSA. The mechanisms and studies designed for components 1–4 (on-farm or modeling tools) are simulated spaces that support the existing niches of innovation. Based on the findings, the implementation of a monitoring system is an essential aspect of the VSA procedure, which helped determine whether the process is along the right lines and whether adaptations were necessary for the work. The results also help to determine if the process of farming participation must be conducted in a monitoring system. Nonetheless, in situations where farmers and even regional stakeholders are unable to track and report what they are doing, the monitoring system may be strong in terms of quantity and diversity data collection (agronomic, environmental, and social data). Despite improving the knowledge, attitude, and skills of farmers, this study did not clearly specify the threshold used to decide on participation. To prevent frustration, such a threshold must be explained to the platform participants from the outset of the CSA design process, as proposed by Vall et al. (2016).

5.4. Prospect future

As seen in previous parts of this article, VSA is part of tackling climate change. It is crucial to realize that governments need to prioritize developing capabilities and capacity, both as a short-term and long-term initiative such as VSA, as the realities of climate change begin to unfold. Sufficient services need to be made available in order to increase the effectiveness of organizations responsible for raising public consciousness and informing all aspects of society about climate change. In addition, disadvantaged and marginalized groups in rural communities, such as women (Goli et al., 2020) and small-scale farmers (Burnham and Ma, 2017) are more vulnerable to climate change and have special needs for adaptation, and thus VSA strategies need to consider various problems affecting different groups and can be adapted to specific needs (Zamasiya et al., 2017).

Adaptation at all stages must be grasped and perceived within the parameters of the local context. In order to help farmers with less education and science expertise, the enforcement of agricultural extension institutions is also necessary to successfully implement the suggested VSA adaptation strategies. Every developed country tends to have government extension programs to help small-scale farmers in particular, but due to a variety of reasons, they usually fail to have an impact. Any of the fields requiring intensive VSA enhancement to supplement government extension programs are as follows:

- Proper VSA training and new strategy training provided to small-scale farmers should be appropriate and expected to overcome the real challenges.

- The productivity of the government agriculturalist extension agent should be able to grasp the production system of target farmers and be able to take advantage of VSA's large baseline study results, placing it in a particular sense that better fits adaptation requirements in unique climate locations.
- Participatory approach-farmers need to be active in all efforts to find solutions to their agricultural challenges, so VSA targets need to be driven by farmers themselves, and most VSA methods need to be checked at farmers' sites.
- Availability-extension facilities should always be available to small-scale farmers when they need them, adequate numbers of farmers should concentrate on specific areas, and farmers should always be visited for observations and guidance on the VAS approach.

In general, due to limited capital and information power, small-scale farmers in developed countries are less successful in adapting their farming strategies in response to climate change. Given the present and potential developments in climate change, rising soil loss, and socio-economic pressure, in order to achieve sustainable farming, all countries around the world need to break ground in the CSA and VSA practice and contribute to mitigating global climate change. It is also strongly encouraged to use VSA techniques, proposals, and viewpoints that define synergies and trade-offs between food security, adaptation, and mitigation as a framework for advising and reorienting climate change response policies.

6. Conclusion

In this study, an innovative conceptual framework was introduced including five main elements based on the small-scale farmers' livelihood capitals. The study demonstrated the vulnerable status of small-scale farmers, their high-risk exposure, and the immediate need to reduce their existing and potential risk vulnerability. The research findings also indicate some possible fields to be explored by policymakers that could help raise agricultural production and strengthen livelihoods using VSA concept in the short-term.

First, there is an immediate need to recognize the important role of small-scale farmers in order to provide technical knowledge and training on best management practices for planting, harvesting, and crop storage, as well as enabling farmer-to-farmer learning. It has been seen that strengthening small-scale farmers is vital when persuading them to adopt agricultural practices in response to climate change. Careful screening of these strategies and participatory action-oriented research with farmers should be recognized in order to collectively define and incorporate adaptation solutions that are feasible and efficient, and to ensure that these alternatives have no negative or unintended impacts on farmers' livelihoods.

Second, small-scale infrastructure investments, such as improved irrigation systems or seed storage facilities, are a low-cost incentive for policymakers and donors to assist farmers in increasing productivity and better securing their harvests. Small-scale farmers are very keen on developing local infrastructure, but seldom have the resources required to support these operations. Such small-scale infrastructure can be further supported by the governments and organizations operating in rural areas through the creation and accessibility of micro credits and subsidies to farmers or local farmers' associations. VSA proposes to start implementing project results with farmers' advisory programs to introduce smart technology and innovation models based on sensors and data sources which highly rely on farmers' knowledge. VSA will seek to involve agriculturalists (especially agricultural economists), geographers, environmentalists, meteorologists, and anthropologists in the implementation of the advisory component of this program, according to their specific expertise and program needs. It should be noted that the major contribution of this study is to enrich CSA concept by adding the neglected but very important element "human factor"; i.e., "small-scale farmers". Accordingly, there is an urgent need to involve socio-economists and policy analysists who are active in climate change, environmental, and agri-rural issues when designing a VSA system. Many farmers currently rely on informal assistance from families and friends in these extreme circumstances, as formal protection networks are lacking.

Third, in order to ensure that farmers could be supported properly, it is important to promote farmers' access to financial resources. New services, such as mobile payment systems, which work efficiently even in rural areas, provide families and friends with a significant new, affordable, and safe means of exchanging money even though they are not geographically close to each other. VSA, as a more feasible, strongly believes that only if small-scale farmers are active in setting the agenda, fundamental changes can be made, so farmers would make a significant contribution to their financial betterment.

Fourth, the government and policymakers should be able to make a clear distinction between the goals and capacities of small- and large-scale farmers. Therefore, in order to improve the future prospect, more focus is needed on new techniques and technologies which address the issue of “farmers’ scale” and increase their participation in the use of these technologies in order to develop the initial paradigm of CSA and provide a more complete version; called VSA. Therefore, the key results of this study can be used to improve future methods and mechanisms for resilience evaluation and provide a potential starting point for further quantitative and qualitative farming resilience studies. Overall, it is necessary to reconsider how to build a resilient farming system by emphasizing the status and livelihood of small-scale farmers.

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