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The value of indigenous knowledge for enhancing smallholders' resilience to climate change and food insecurity: a case study of small-scale irrigation system in Niger

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ABSTRACT

The global south faces challenges in enhancing smallholder farmers' resilience to climate change and food insecurity. Indigenous knowledge and small-scale irrigation (SSI) systems are being promoted as a viable solution to address these challenges. This paper explores how smallholder farmers use local knowledge to establish informal and farmer-led SSI to enhance smallholders' resilience in agriculture and livelihoods. A qualitative research approach with 79 semi-structured interviews was carried out with farmers' households in Tamaske rural community in Southwest Niger, followed by thematic and statistical analysis. The results revealed that an alternative SSI strategy is mostly based on internal agencies rather than externally supported and it serves as a tool to enhance household food and income security amid climate change. The empirical case allows us to assess the value of indigenous knowledge in agriculture by asking how local people can bring together ideas and resources to enhance SSI and build resilience to climate change. The study suggests that the initiation and multiplication of SSI systems can be achieved by farmers' own agencies if appropriate technology and cooperation mechanisms are selected. The policy focus should promote simple, root-based technology as limited government financial support in the global south may hinder this progress.

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1. Introduction

While the world, through Sustainable Development Goals (SDGs), intends to end hunger and achieve food security by 2030, the number of food-insecure populations is still high and tends to increase day after day. The number of food-insecure populations increased to more than 800 million during the pandemic, with projections indicating that the number of hungry people will be more than 600 million in 2030 (FAO et al., 2022, 2023). The post-pandemic period is experiencing a slight decrease in the number of food-insecure populations, where it is estimated that in 2022, between 690 and 783 million people in the world faced hunger (FAO et al., 2023). Inequality regarding food access is still the world's major challenge towards achieving food security. Although global crises such as the Covid-19 global pandemic and the war in Ukraine are reported to increase food insecurity (FAO et al., 2023; Mkupete et al., 2022), climate change is highly cited as one of the root causes of food insecurity in many developing countries from the Global South particularly in sub-Saharan Africa (hereafter SSA) (Madamombe et al., 2024; Tadese et al., 2022). Statistically, a high

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number of food-insecure populations (about 40%) are located in the Global South, mainly SSA, Asia, and Latin America (FAO et al., 2023). At the local level, rural smallholder farmers, children, women, and the elderly are the most vulnerable to food insecurity and climate change compared to other societal groups (Carducci et al., 2021).

In the context of climate change and food insecurity in the Global South, the main challenge facing developmental professionals is how to enhance smallholder farmers' resilience via appropriate technological and organizational strategies to effectively use various resources and opportunities (Mbuli et al., 2021). The call to rethink and transition from conventional development paradigms to understand intrinsic dynamics and innovative potential among smallholder farmers has been largely promoted over the past few decades due to the mismatch between the theory and practice of food security and climate change adaptation (Raj et al., 2022). Irrigation agriculture has become a widely recognized approach to building smallholder farmers' resilience to climate change and food security in many countries in the Global South, particularly SSA (Higginbottom et al., 2021). Nevertheless, governments' support in irrigation farming has been mainly focused on large-scale irrigation schemes that, in most cases, do not benefit most smallholder farmers (Woodhouse et al., 2017). Farmer-initiated and farmer-managed small-scale irrigation (SSI) systems via small but appropriate knowledge and technology have been gaining more attention as a feasible strategy for smallholders to cope with various challenges and constraints from limited resources, uncertainties in climate, and markets for their livelihood security. In this study, SSI is defined as irrigation activities that involve a small spatial extent, which does not normally exceed 10 hectares per farm family and may be as little as 0.1 hectares with local farmers highly involved in planning, initiation, development and management. It further relies on locally available resources and technology (Smith et al., 2014). Nevertheless, farmer-initiated and farmer-managed SSI systems are highly neglected in theory and practice in the SSA (Woodhouse et al., 2017).

In Niger, climate change has severely impacted the country's food situation with severe impacts on the large population of rural communities which rely on small-scale subsistence farming to sustain their livelihoods. Sahara desert covers a large part of Niger, and hence rainfed agriculture provides no solution to poverty reduction, elimination of hunger and building resilient livelihoods for smallholder farmers (Alvar-Beltrán et al., 2023). Desertification is also increasing rapidly. According to the data from the national statistics centre of Niger, more than 100,000 hectares of land get lost annually due to soil erosion and desertification (Zakari et al., 2022). Desertification is also extending to other West African countries. The unpredictability of rainfall increases the vulnerability of the majority of rural people who rely on rainfed agriculture, with devastating impacts on socially marginalized groups of women, children, and the elderly (Adisa, 2020). The combined effects of climate change, desertification, prolonged droughts, and sporadic rainfall in Niger are raising the question of how Niger is going to feed its rapidly growing population, which is projected to reach 30 million by 2030 and 70 million by 2050 (World Bank, 2021). How do or can smallholder farmers build resilience against global climate change shock? Irrigation agriculture, more specifically SSI, is considered to be one of the effective and long-term strategies to solve the problem of food insecurity, reduce poverty and improve rural livelihoods in Niger (Ado et al., 2019).

This paper aims to explore the value of indigenous knowledge in enhancing smallholders' resilience in the Global South by pointing out how smallholder farmers bring together ideas and resources to build resilience against food security and climate change using SSI. In this study, indigenous knowledge is understood as local people's ability to understand and adapt to the changing local environmental conditions, such as weather patterns and desertification, directly impacting the production system. Indigenous knowledge helps local people to make their own decisions and choices when they face challenges. This research was carried out in a context where indigenous knowledge plays a significant role in initiating climate change adaptation without external interventions, which often can't reach remote and marginalized areas. The contextualized and endogenous approaches to reducing the vulnerability of local communities through indigenous knowledge of SSI could also shed light on those debates on international adaptation interventions' effects, within which some reinforced and created new sources of vulnerability (Eriksen et al., 2021).

2. Literature review

2.1. Agriculture, climate change, food security, and small-scale irrigation in Niger

Agriculture remains the backbone of the economy of Niger and is the main sector contributing to more than 40% of the country's GDP (Kalidou et al., 2024; World Bank, 2021). The sector employs the majority of rural dwellers, who account for about 80% of the country's population (World Bank, 2019). Most of the population depends on rainfed agriculture, which is highly impacted by the effects of climate change, especially prolonged droughts (Adisa, 2020). Food insecurity is a common problem for most rural poor, especially during the poor harvest years or dry seasons (Zakari et al., 2014). As it is in many other SSA countries (Ndimbo et al., 2023), smallholder farmers in Niger suffer from low yields due to the short growing season, low soil fertility, changes in maximum and minimum temperature, and lack of desirable inputs like fertilizers and drought-resistant seeds (Sarr et al., 2015). The ability of farmers to purchase inputs is limited by a lack of funds (Graefe et al., 2008), and the labour force in rural areas is highly limited due to the problem of rural-urban migration of the young generation.

In many sub-Saharan African countries, including Niger, climate change remains one of the main contributors to food insecurity, hunger, and famine for most of the rural population. Given the fact that Niger is characterized by a Sahelian climate, droughts and desertification are increasing day after day, posing negative impacts to the population, particularly smallholder farmers. Nevertheless, for many years, the government of Niger has been working hard to support irrigation schemes to promote food availability through out the year and enhance food security. For instance, after independence, the government of Niger put in place a lot of effort to ensure that agricultural development meets the growing national demand of both rural and urban populations. Though for a long time, the government of the Republic of Niger has been putting more emphasis on large-scale irrigation while neglecting SSI (Olayide et al., 2020). Given that scarcity of rainfall is the main challenge hindering smallholder farmers in most parts of the country, 'the development of irrigation has always been regarded as a key aspect of the sector's development. In the last decade, the focus has been placed on developing small irrigation perimeters, whose implementation is less consuming in terms of capital and time than large infrastructures' (Tillie et al., 2016). Small-scale irrigation, defined as small-scale irrigation projects initiated, organized and controlled by local farmers using simple technology and local knowledge (Smith et al., 2014), has been highly promoted by the Nigeren government in the past decade.

In order to support the agricultural development plan and promote rural food and income security, the government of the Republic of Niger established a new framework aiming at improving agriculture and rural livelihoods. The new framework, 'Initiative 3N', which stands for the French phrase '*Les Nigériens Nourrissent les Nigériens*', which means 'Nigeriens Feed Nigeriens' was launched in 2012 (The Republic of Niger, 2016). The main focus of this plan is to ensure Nigeriens produce enough food for their domestic consumption without depending on food from outside the country. The plan aligns with SDGs and sustainable rural livelihood strategies where countries should ensure food security amid disasters, including global climate change, by supporting smallholder farmers in accessing necessary agricultural inputs (Dedehouanou et al., 2018). To achieve Initiative 3N, SSI has been given a very strong emphasis by the government of Niger since the majority of the population in Niger lives in rural areas and relies on agriculture for their survival. The shortage and unpredictability of rainfall in the past few decades have forced the government of the Republic of Niger to put more emphasis on small irrigation as a solution for rural income and food security. Irrigable crops, particularly horticultural crops, are an alternative to cereals and suitable for food and income generation (Ministère de l'Agriculture, 2015).

While the government of Niger is promoting SSI as a solution to rural poverty and hunger, the situation turns worse in many parts of the country, particularly in rural areas. In its plan to promote SSI, the government puts more emphasis on areas along the Niger River basin while neglecting other areas. How SSI take place in areas beyond the Niger Basin and how the smallholder farmers in areas beyond the Niger river basin create their survival strategies through SSI remains undocumented. This study adds knowledge to the growing

body of literature on smallholders' resilience to food security and climate shocks by exploring how farmer-initiated and farmer-managed SSI systems can help to reduce vulnerability to food insecurity and build resilience among rural households in Niger.

2.2. The debate on indigenous knowledge and resilient rural livelihood

Over the past few decades, the indigenous knowledge system has been widely recognized as an essential catalyst in designing and implementing sustainable agricultural systems and building resilient rural livelihoods. Indigenous knowledge can be defined as the sum of experience and knowledge of a given ethnic group that forms the basis for decision-making in the face of familiar and unfamiliar problems and challenges (Mistry et al., 2019). It is highly influenced by a certain locality's socio-economic and environmental reality (Beckford & Barker, 2007). The wide appreciation of the indigenous knowledge system is due to farmers in agrarian societies having ways of looking at the world and addressing different challenges based on their local knowledge and technologies. Nevertheless, indigenous knowledge has long been overlooked in favour of Western scientific knowledge and is deemed to disappearance (Ajani et al., 2013; Juanwen et al., 2012). Consequently, many technological solutions proposed to address problems in rural communities have failed because they do not consider the local culture, particularly society's preferences, skills, and knowledge. It is, therefore, stated that the involvement of local people in the planning and implementation is key to the success of any rural development project (Mafongoya & Ajayi, 2017).

For centuries, farmers in agrarian societies have relied on local knowledge to survive in different shocks, including food insecurity and climate change (Beckford & Barker, 2007). This kind of knowledge has been increasingly revisited and promoted from the mid and late twentieth Century due to its significance in enhancing resilient rural livelihoods. The emphasis in rural development planning and implementation has changed from over-relying on Western scientific knowledge alone, which excludes the rural people, to what Robert Chambers calls '*putting the last first*' (Chambers, 1983) with a strong emphasis on indigenous knowledge. Among the local climate change adaptation strategies is adopting informal and farmer-led SSI systems (Ajani et al., 2013). This climate change adaptation strategy is widely used in many developing countries to build resilient livelihoods amid climate change and food insecurity disasters, although its recognition is still very low (Woodhouse et al., 2017).

In this study, indigenous knowledge describes why and how smallholder farmers from remote and poverty-stricken areas use their limited resources, knowledge, and skills to develop informal, farmer-initiated, and farmer-managed SSIs to build resilience to food security and climate change. Indigenous knowledge enables local people to take charge and develop in their own hands as self-reliant development actors instead of relying entirely on external support and responsibility for their own development (Bock, 2016). This notion of indigenous knowledge is fundamental to successful and sustainable rural transformation, inclusive growth and building resilient rural livelihoods (Grimm et al., 2013). While emphasizing the indigenous knowledge, the important role of the scientific knowledge should not be neglected. It is argued in this paper that integrating the two knowledge systems would enhance sustainable and resilient small-scale irrigated agriculture. Merging local knowledge with modern science in Africa could help develop syncretic agronomical knowledge among farmers in handling climate change (Apraku et al., 2021). Support from the government and other development agencies on merging scientific and local knowledge and technologies could better help more rural populations engage in SSI and build resilience to climate change and food security.

In developing countries, particularly in sub-Saharan Africa, the indigenous knowledge system has been widely embraced to build resilience against shocks and help people overcome climate change, variability, water shortage and other related challenges (Eriksen et al., 2021; Jiri et al., 2016; Leal Filho et al., 2022). Indigenous knowledge systems are used to predict and create adaptation strategies to erratic rainfall, increases in temperature, and other natural and human-induced challenges that harm people's lives (Jiri et al., 2016). Empirical research carried out in Malawi shows that through local knowledge systems, local communities can recognise the changes in their climate and regional environment, such as the delayed and unpredictable onset of rainfall, declining rainfall trends, warming

temperatures and increased frequency of prolonged dry spells. The community also use their indigenous knowledge system to partially adapt their agricultural systems to offset the effects of climate change. Like vulnerability to climate change, the indigenous knowledge system varies over a short spatial scale, providing locally relevant adaptation to the impacts of climate change (Nkomwa et al., 2014).

3. Methodology

3.1. Description of the study area

This study was carried out in the Tamaské rural community, which is located in Keita Department, Southwest Niger (Figure 1). There are 14 administrative villages in the Tamaské rural community. The community was founded by law No. 2002–014 on 11th June 2002, covering an area of about 765 km^2 (INS, 2014). Based on the 2012 General Population and Housing Census, Tamaské rural community has a population of 111,358 inhabitants, of which 54,349 are men (48.80%) and 57,009 are women (51.20%). The active labour force aged 15–49 is 41,590 (39.14%) of the total population (INS, 2014), which means that the area has a very active human potential for agriculture practiced in all commune villages. The different ethnic groups (Hausa, Peulh, and Tuareg) are mainly sedentary and use Hausa as their main language of communication. The climate of the study area is the Sahelian climate, which is characterized by two seasons, namely, the dry season and the rainy season. The dry season begins from October to June. It includes a cold period (October to February) with temperatures dropping to 15°C and a warm period (March to June) with temperatures of up to 45°C. As for the rainy season (July to September), the average temperature is around 27°C. The average annual rainfall in the area is 471.4 mm (Karidjo et al., 2018).

Small-scale subsistence agriculture is this area's primary source of food and income. Based on recent data from the Tahoua region, Tamaské rural community has 15,713 households, of which 13,102 are agricultural. Since small-scale rainfed subsistence farming is dominant in this area, the majority are unable to meet the food needs of their families due to low productivity, mainly associated with climatic variability, recurrent drought, and limited agricultural investments. Besides, poor agricultural techniques have raised environmental degradation and resource-use conflicts. The uneven distribution of rainfall over time and space, parasitic pressure, and insufficient agricultural production inputs (modern seeds, fertilizers, pesticides, etc.) result in low agricultural productivity and make farmers vulnerable to food

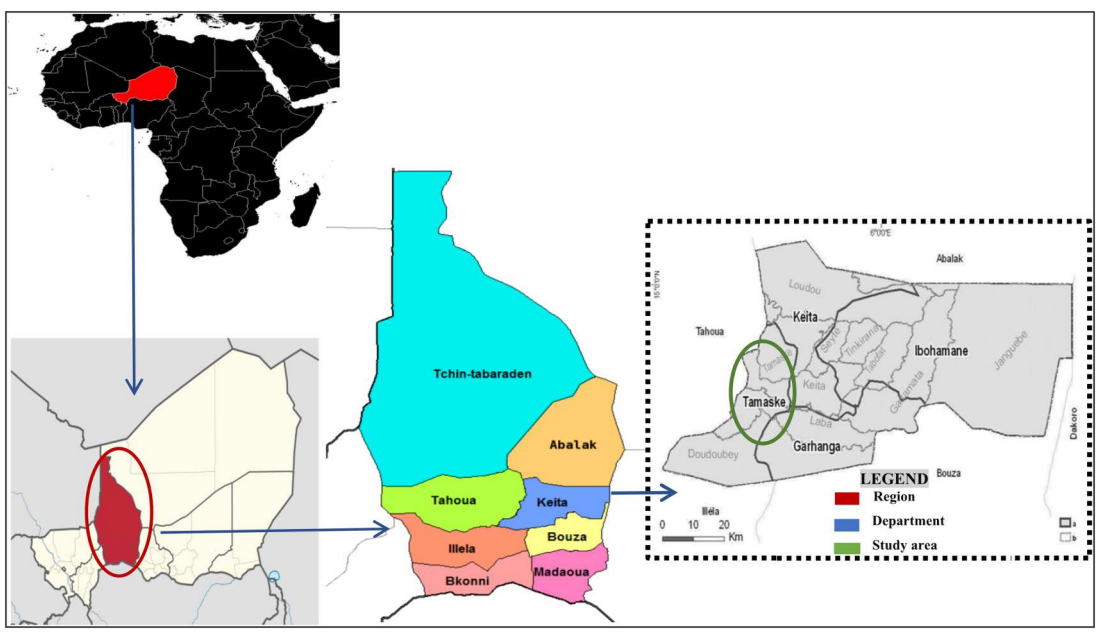

Figure 1. The map showing the study area. Source: PDC 2020.

insecurity. SSI serves as a survival strategy and helps improve households' food security to a certain extent. Smallholder farmers mainly produce and sell horticultural crops such as onions, tomatoes, and vegetables to supplement food shortages. In the Tamaské rural community, onion is the main irrigation crop, which provides significant monetary income to producers, who export it to coastal countries like Côte d'Ivoire, Benin, Togo, and Ghana, to mention a few.

3.2. Data collection

As stated earlier, this paper intends to understand how smallholder farmers use indigenous knowledge to build resilience against food insecurity resulting from climate variability and recurrent droughts. The paper follows a qualitative research approach that explores people's subjective opinions, beliefs, attitudes, behaviours, interactions, and experiences (Mohajan, 2018; Percy et al., 2015; Walia, 2016). The study employed a non-random sampling with purposive and snowball sampling techniques to recruit respondents from households engaging in SSI. Purposive sampling was used to obtain suitable respondents, particularly those who engaged in SSI in the study area, to help answer the research question. Through purposive sampling, the researchers selected the 'information-rich' respondents who were proficient and well-informed concerning SSI (Etikan, 2016). The SSI households that were selected purposely also helped the researchers to identify other respondents who engage in the same activity. This technique, the snowball sampling technique (Parker et al., 2019), helped the researchers to save time since the rural households who engage in SSI agriculture easily know each other as they share different resources, including land, water, and other valuable resources for irrigation agriculture as well as knowledge, skills, and experiences in adapting to the climate variability and recurrent drought.

The primary data were collected through semi-structured interviews with the 79 heads of households, two rural development officers, one official from the local government authority, and one agricultural extension officer from the Keita Department of the Tamaské rural community in Southwest Niger. Some of the questions asked during the interviews include: *Why did you opt to engage in SSI? What kind of knowledge and technologies do you use in SSI? What kinds of crops do you grow through SSI? What kind of support do you get from the community and family members to improve SSI? What kind of support do you get from agencies like the government and organizations? In what ways does the SSI help your family to improve food security and your general welfare? What are the obstacles hindering the effective implementation of SSI as an approach to building food resilience?* The semi-structured interview was chosen because it allows the researcher to probe the respondents and revise questions to obtain detailed information related to the study question (Brown & Danaher, 2019; Kallio et al., 2016). The face-to-face interviews with each respondent took an average of 45 minutes.

3.3. Data analysis

The heads of households from each selected household were interviewed based on their availability and willingness to participate in this study. All interviews were conducted in the local language (Hausa) since most villagers were conversant. Respondents were also asked for consent to allow the researcher to record the interview conversations using a sound recorder. After the interviews, all the information was transcribed and later translated into English for analysis. From the transcribed data, researchers were able to find out the main themes that were used to guide the analysis. Simple descriptive

Table 1. Socio-demographic characteristics of the respondents.

Variable	Frequency (N = 79)	Percentage (%)
Age		
Less than 20	8	10
20–29	11	14
30–39	15	19
40–49	18	23
50–59	21	27
60 and above	6	8
Sex		
Male	63	80
Female	16	20
Education		
No formal education	71	89.9
Primary	6	7.6
Secondary	2	2.5
Land size (ha)		
<1	27	34.2
1.1-1.5	31	39.2
1.6-2.0	11	13.9
2.1-2.5	5	6.3
2.6-3.0	3	3.8
>3.1	2	2.5
Ratio of livestock		
Non-livestock keepers	57	72.15
Livestock keepers	22	27.84

statistics were also employed in this study to analyze the socio-economic characteristics of respondents, such as age, sex, education level, landholding size, income, and the respondents' livestock ratio (Table 1). The Statistical Package for Social Sciences (SPSS) was used to analyze demographic information. Using descriptive statistics was appropriate in analyzing the socio-economic variables of this research.

3.4. Analytical framework

The analysis is guided by a resilience framework (Béné et al., 2015; Frankenberger et al., 2012). Cutter and colleagues define resilience as 'the ability of human systems to respond and to recover. It includes those inherent conditions that allow the system to absorb impacts and cope with the event, as well as post-event adaptive processes that facilitate the ability of the systems to recognize, change and learn in response to the event' (Cutter et al., 2008). Resilience is coping with various threats, including climate change and other natural or social hazards. Resilience does not only imply resistance to threats; it goes beyond identifying how possible and/or quick someone can get out of the shocks. 'A high level of resilience implies greater opportunities for absorbing external shocks and successful adaptation to social and environmental change. Low resilience means the vulnerability to externally imposed change is greater, i.e. adaptive options are limited' (Adger & Kelly, 2012).

In the context of this study, natural hazards like climate variability and prolonged droughts are considered to be the main causes of vulnerability, leading to food insecurity among rural poor households (Figure 2). The resilience framework adopted in this study integrates the attributes of the sustainable livelihoods approach (Scoones, 1998, 2009, 2015; Serrat, 2017), disaster risk reduction, and climate change adaptation. Informal, farmer-initiated and farmer-managed SSI is considered an important resilience strategy designed and developed by smallholder farmers to enhance their resilience to food security and livelihoods in general. The resilience framework by Béné et al. (2015) is similar to that of Frankenberger et al. (2012) as they both conceptualize resilience as consisting of the:

> Context, level of aggregation, disturbance, exposure, adaptive capacity, sensitivity, resilience and vulnerability pathways, and livelihood outcomes (e.g. food security). The framework links resilience pathways to food security in a given context via ex-ante preparedness and prevention as well as ex-post response and recovery mechanisms. Given that the ex-ante preparedness is strong, households stand less risk of experiencing food insecurity when shocks occur.

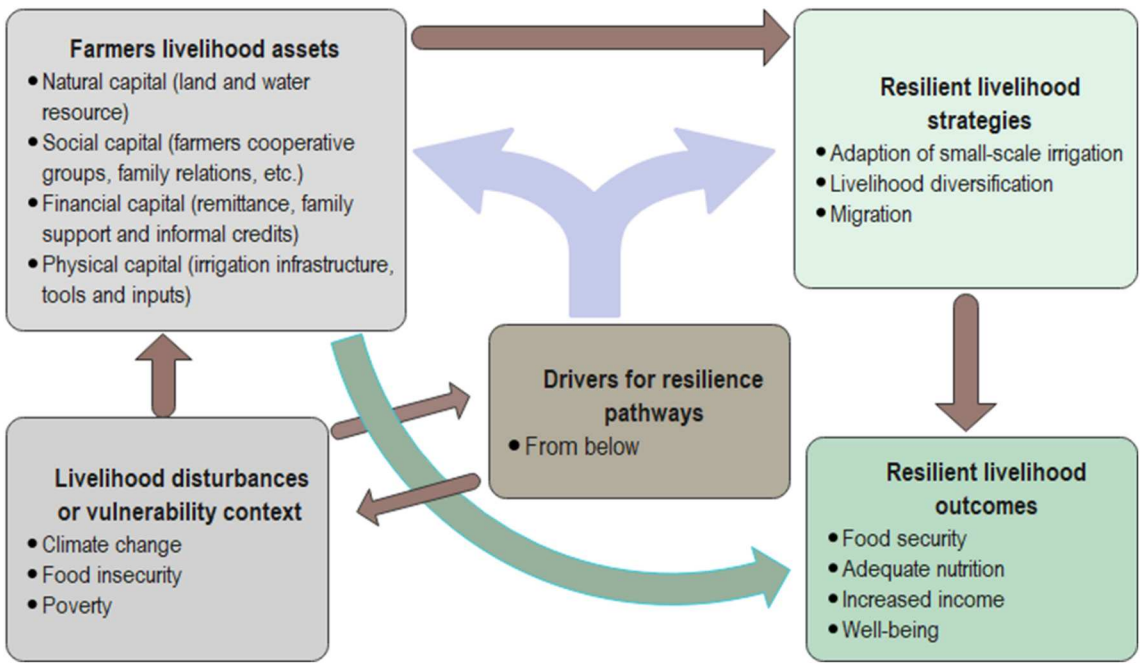

Figure 2. Farmers' resilient livelihood framework. Source: Adopted from (Béné et al., 2015; Frankenberger et al., 2012).

It is emphasized that resilience strategies always come from the grassroots and that smallholder farmers have their indigenous mechanisms to step out of the shocks using both absorptive, adaptive and transformative capacities by using different livelihood resources, including natural capital (land and water resources), social capital (farmers' cooperatives and groups and family relations), financial capital (remittances, family support and informal credit), human capital (local knowledge, skills and technologies) and physical capital (irrigation infrastructure, tools and inputs). Nevertheless, combining these local resilience efforts and mechanisms with external support from the government and other development stakeholders is crucial for building sustainable resilience to food security amid climate change.

4. Results

4.1. Demographic and socio-economic characteristics of the respondents

To obtain a holistic overview of the households engaging in SSI, the authors surveyed the demographic and socio-economic characteristics of the respondents. Patrilineal family structure is dominant in the study area and Niger as a whole. The survey targeted the head of household (man), and where a man was missing due to death, temporary migration, or engaging in activities other than agriculture, a woman was considered the head of the household by chance. All the 79 surveyed households engage in SSI. Most respondents (82%) were aged between 20 and 60. A few respondents (18%) were aged below 20 and above 60. This implies the area has enough active labour force to engage in economic activities. Based on gender, most of the respondents were male (80%). Most respondents (89.9%) have not obtained formal education. Many of them had dropped out of school or failed to attend formal education due to the ongoing political unrest in Niger. Some respondents also keep a limited number of animals (27.84%) and use animal manure to increase soil fertility and improve productivity.

Most respondents own a limited land of less than two (2) hectares. In Niger and Tamaské rural community, in particular, the customary land tenure system, both *de facto* and *de jure,* is still dominant (Benjaminsen et al., 2009). Most respondents own a small piece of land inherited from their forefathers. Based on this land ownership, SSI farmers cannot use their land as an asset or collateral to get loans from formal financial institutions. The engagement in SSI does not need someone to own the land; instead, one may ask for a piece of land from neighbours, friends, or family members by paying a small amount after harvest. Most rent 0.5 hectares for 15,000 FCFA, equivalent to 23 USD annually. Villagers also keep a limited number of animals and use animal manure to increase soil fertility on irrigated farms.

4.2. Characteristics of small-scale irrigation in the study area

It was essential to describe the characteristics of small-scale irrigation in the study area to provide a holistic picture of the operation of SSI. First, SSI in the study area involves a small spatial extent, usually less than one hectare. Based on the data obtained from the study area, very few farmers owned more than one hectare of irrigable land. The second feature is technology. SSI in the study area uses simple and affordable technology for the farmers. For example, farmers rely on water from rivers and ground to acquire water for irrigation. While the use of surface water is very common to most farmers, a limited number of farmers use new irrigation technologies like motor pumps for dewatering, pedal pumps, irrigation water pump generators and traditional sumps. Irrigation pumps are only used where surface water flow is limited. However, this is not a common practice for poor farmers as their ability to afford irrigation pumps is very limited compared to commercial-oriented or affluent farmers. For water distribution, open-earth canals are mainly employed. Water cans and baskets are mainly used for irrigation in small plots, usually by women and children. Relying on high irrigation technology is considered impossible as most farmers could not afford it due to limited financial and social capital. The third feature is that of informal, farmer-initiated and farmer-managed. In this area, SSI is informally organized and relies on the knowledge and skills of farmers themselves (indigenous knowledge). Farmer-to-farmer sharing of irrigation knowledge, skills, technologies and experiences is common in the study area. Local people are responsible for all matters related to the development and maintenance of irrigation infrastructure. Finally, since the investment is always from the farmers, SSI uses a very small amount of capital. However, low capital investment in SSI limits its efficiency and productivity, as higher investments would lead to higher returns.

Table 2. Factors encouraging farmers agency for SSI.

Dimension	Factors	Sources	Percentage of respondents with access to the factors (%, n = 79)
Natural capital	Land and water	Primary natural landscape	100% with irrigable land
Human capital	Skillful labour	Indigenous knowledge application	80% with age of 20–60 years
Social capital	Cooperatives	Community culture	100% experienced collective action of *gayya*
Financial capital	Remittances, income from the market	Linkage with outside of village	45% received remittances from their family members to support SSI
Physical capital	Local irrigation infrastructure and facilities	Inheritated and family-owned assets	100% of farmers owned a certain kind of irrigation facility, whether traditional or modern.
Integration of capitals	Factors complement each other	Symbiotic relationship	20% without skilful labour was complemented with *gayya*

4.3. Systematic factors encouraging the internal agency for SSI

The Tamaské rural community has various models of SSI, which are implemented properly by some smallholders and contribute to local food security and livelihood standards. In this section, the researchers analyze why those smallholders can develop and use SSI systems to build resilient livelihoods and the implications of involving more smallholders in SSI applications. It is argued that in nature, the human being is a rational creature who can understand the circumstances and consequences of their actions and thus exercise choices. That is to say, humans are knowledgeable agents. This is particularly relevant in the study area as SSI farming has become the main choice of smallholder farmers as a resilient mechanism for many decades. The role of individual farmers and the community has led to some, though not significant, improvements in food availability and life standards for those who engage in SSI. The local community in the study area (individual farmers and farmers' organizations) works collaboratively to improve SSI and their well-being. Some of the systematic factors encouraging smallholder farmers in this remote and poverty-stricken area to successfully engage in SSI with limited support from external agencies are analyzed herewith. As per the study's analytical framework, different livelihood assets such as natural capital (land and water resources), human capital (local people's knowledge, skills and technology), social capital (labour relations, farmers' cooperatives and family supports) and financial capital (remittances, family support and informal credits), physical capital (local irrigation infrastructure, tools and inputs) and availability of market opportunities are the main factors encouraging the internal agency for SSI in the study area (Table 2). The details of each factor encouraging the internal agency to implement the SSI are below.

4.3.1. The availability of natural capital

As one of the important natural capitals, the land remains one of the most valuable assets and the major means of production in agrarian communities. The respondents of this study mainly cited the availability of irrigable land as one factor encouraging many smallholder farmers to engage in SSI. According to the Directorate of Agriculture of the Keita Department, the Tamaské irrigable land is estimated to be more than 3,650 hectares, and only 1,238 hectares have been developed. The relief of an area is partly characterized by flat land, which creates room for irrigation agriculture to take place. Given the landscape's nature, the flood plains' land is more fertile than in hilly and mountainous areas, making it easy for the local farmers to use simple irrigation technology to grow crops. Land in this area is owned under customary law, and none of the respondents had a formal land title. Nevertheless, engagement in SSI does not require someone to own the land they till. Community members who own irrigable land share it with those who do not own irrigable land. This culture of sharing irrigable land is possible due to the social life lived by rural dwellers, who always treat each other as brothers and sisters. Traditional leaders and elders, therefore, encourage people to learn to share what they have with others for the well-being of society. Sharing resources in this community has been inherited from generation to generation and has enabled local people to survive even in hard times, like during hunger and other natural disasters.

Sharing irrigable land makes almost all community members grow cash and food crops through the SSI system, building resilience to food security and the economy throughout the year. This practice reminds us of the famous African philosophy of '*ubuntu*' that, according to (Turaki, 2006, p. 36), implies that 'people are not individuals, living in a state of

independence, but part of a community, living in relationships and interdependence'. However, it was observed that sharing irrigable land does not mean the land is always shared for free; farmers should pay little to the landowners during harvest. During the interview, one respondent reported as follows:

> I own a large piece of land that is suitable for irrigation. This land was given to me by my parents, who inherited it from our forefathers. I cannot use it alone to grow crops since my family and neighbors need to grow some vegetables and other crops to get food and money. I usually give some land to my children for free and the rest to my neighbours, who always pay me a small amount of money during harvest. I feel pleasure sharing the land with my neighbors because we live as a family; mine is yours, and yours is mine.

The irrigable land is shared with family members, neighbours, and strangers who need to work on it. One respondent who claimed to be a stranger living in the village narrated that:

> Since I came here more than 10 years ago, I have been engaging in agriculture [rain-fed and SSI] to earn a living. I don't own a piece of land, but every season, I get a piece of land from my neighbors either for free or by contributing a small amount of money. Natives here are very generous. They always share what they have with their neighbors. In short, we live as brothers and sisters; even if I don't have food, I can obtain it from my neighbors.

Nevertheless, the availability of irrigable land does not mean that all smallholders can afford to pay to set up SSI infrastructure or facilities. As stated earlier, SSI in the study area is farmer-initiated and managed; hence, its infrastructure is limited to what farmers can do. While the affluent farmers who usually engage in middle-scale irrigation farming, which is highly mechanized, commercialized and modernized, could afford the costs of setting up irrigation infrastructure, the poor farmers only use their limited resources to practice more informal irrigated farming, which gives them low returns as compared to the middle-scale irrigated farming. Minor support from the government or other development stakeholders in infrastructural development could help the smallholder farmers make a difference.

4.3.2. Availability of human capital

With a 3.9% of annual population growth rate and more than 50% of the population aged between 14 and 30 years old, Niger is considered one of the countries with a relatively young population (World Bank, 2021). Most of this population lives in rural areas and works in the agriculture sector, as more than 80% of the total population of Niger lives in rural areas. This is also evidenced in Tamaské rural community, where the active labour force is high. Based on the study's findings, 80% of the respondents were aged 20–60 years, implying that their contribution to the provision of labour power in SSI is also high. Both men and women contribute to providing labour power for irrigated farming. Labour mobilization in irrigated farming mainly relies on family labour, with men and women doing different tasks. For example, while the men prepare the land for irrigation farming, women usually sow seeds and engage in weeding. Depending on the kind of crops, harvesting some irrigated crops, especially onions, is a collaborative process among all family members, i.e. men, women and children.

Besides, smallholder farmers in the study area have a collective traditional work practice called *gayya*. *Gayya* is a collective effort that brings smallholder farmers together to help one another to the land. A smallholder farmer who organizes this invitation has the role of preparing food and drinks for his guests. Usually, this kind of invitation creates harmony and solidarity among the farmers. The duration can be from 8:00 AM to 3:00 PM, while others organize it from 3 to 6 PM. However, at this level of time, the organizer does not need to prepare food for his guests. During the interview, a respondent who has always benefited from *gayya* had this to say:

> Labor mobilization is not a big problem here. We [farmers] usually rely on family labor, and when family labor doesn't work, we can use *gayya*. People here like to work together as a team, making it easy for the farming activity to be carried out very fast and effectively … Gayya brings people together and unites them as one. Gayya is our inheritance.

From the above quotation, it is clear that this voluntary labour mobilization makes SSI farming easy and effective, as the field can be tilled within a short period. As an important part of social and human capital, local labour relations significantly enhance SSI in the study area. The organization of *gayya* shows how local people can collectively use indigenous knowledge systems to address their own challenges. Through gayya, farmers are also able to share knowledge and skills on SSI. Nevertheless, the study area lacks a skilled labour force. As we have shown in the respondents' demographic characteristics, most smallholder farmers in the study area do

not have formal education. This is accompanied by limited exposure to modern irrigation technologies, knowledge and skills. That is to say, labour is available, but not skilled labour. An external agency is paramount to make SSI more fruitful at this juncture.

4.3.3. Financial capital

Financial capital plays a significant role in any investment. In the study area, farmers obtain financial income to be invested in SSI through income obtained from selling crops from irrigation farming and personal savings and remittances. Based on income from markets, Niger as a country has a huge opportunity for agricultural markets, both domestic and external. Rapid population growth increases the high demand for food, increasing production demand. While a large part of the country is desert or semi-desert, which offers limited chances for rainfed agriculture, SSI is used to supplement rainfed production, and the gap between the demand and supply is an incentive for farmers to approach the higher-price market opportunities, particularly for irrigated crops. The domestic demand for irrigated crops is increasing annually, thus necessitating the need to import irrigated crops like rice, maize, and horticultural crops. In 2015, 2016 and 2017, for example, Niger imported 493,615, 436,506 and 479,409 metric tons of irrigated crops, with rice and maize being the leading imported crops. At the same time, exports of irrigated crops, especially onions, increased rapidly from 94,250–100,303 and 160,250 in 2015, 2016 and 2027, respectively (World Bank, 2021). Domestic and external market opportunities create opportunities for small-scale irrigated agriculture, as farmers can easily generate income due to the high market demand for irrigated crops.

In the Tamaské rural community, SSI irrigation offers an opportunity for both domestic and external markets, hence making the off-season supply of food and cash crops possible. Smallholder farmers mainly grow onions as their main irrigated cash crop and rely mainly on the external market. Onions provide large cash income to producers who enjoy high prices from the buyers coming to coastal countries, including Côte d'Ivoire, Benin, Togo, Ghana, etc. A small-scale irrigation farmer who has been engaging in growing onions and other high-value horticultural crops for more than ten years had this to say:

> Actually, the market for horticultural crops is readily available. But if I had to compare domestic and external markets for our produce, I would simply say that the external market is very effective in terms of price as compared to the domestic market. For us [farmers], when we want to enjoy a good price, we have to keep our produce, especially onions, and wait for those guys [businessmen] from nearby countries to come and buy; otherwise, we have to sell at a lower price.

From the above quotation, it is clear that SSI farmers enjoy a readily available domestic and external market for their produce, with the external market helping farmers obtain high prices. The income obtained from selling onions is used for consumption and re-investment in SSI and other livelihood strategies. However, in some cases, the small-scale irrigated farmers did not enjoy such a high price. Due to poverty, some smallholder farmers pre-sell their irrigated crops before the harvest. In contrast, many others sell their irrigated crops soon after harvest. Intermediaries and some wealthy farmers or rural traders enjoy the better price of onions. They can buy them from the small farmers soon after harvest, keep them, and sell them to foreign merchants during the low onion seasons. The study revealed several other reasons for smallholder farmers' pre-selling or early selling of irrigated crops, which are accompanied by poverty. Firstly, it was observed that the lack of modern storage facilities forced farmers to sell their irrigated crops, particularly onions, soon after harvest. Keeping them longer would accelerate the post-harvest loss. As one farmer narrated:

> How can I keep onions for a long time and wait for a better price when I do not have the ability and facilities to keep onions for a long time? All onions will spoil and get more lost if I keep them. Rather than getting loss, I chose to sell as soon as I harvested from the farm, despite selling at a meager price.

Secondly, limited livelihood strategies, as most rural populations rely only on agriculture, make most smallholder farmers vulnerable to debts from affluent farmers or rural merchants, forcing them to sell their irrigated crops before or soon after harvest to repay the loans. Integrating support from external agencies like government and development partners could make the SSI more fruitful for smallholder farmers.

4.3.4. Social capital

As an important part of social capital, formal and informal groups or cooperatives play a crucial role in

enhancing smallholders' internal agency for SSI amid climate change. Findings obtained during this study revealed that due to limited support from the government, some farmers have joined their efforts to establish a farmers' cooperative that enables small-scale irrigation farmers to share knowledge and experience on issues related to irrigation. In some cases, this cooperative is an important tool that helps farmers address their needs and concerns to the government and get support from the government. During the interviews, one respondent reported that:

> A cooperative mainly helps us learn how to cope with the hazardous effects of climate change. It also allows us to learn how to integrate our own understandings [local knowledge] with outsiders and create resilient livelihood strategies to shocks.

Nevertheless, some households, especially those with strong social networks, prefer not to join cooperatives since they can get support in terms of remittances from their family members, particularly children or relatives who live and work in urban areas or abroad. The support usually ranges from money and material support like irrigation pumps, seeds and fertilizers. It thus helps to enhance SSI farming and build households' resilience to food security amid climate change.

4.3.5. Physical capital

In the context of SSI, physical capital involves the necessary infrastructure and facilities needed to sustain irrigation. Most farmers in the study area use simple and affordable technology and irrigation facilities. For example, farmers rely on water from rivers and ground to acquire water for irrigation. While the use of surface water is very common to most farmers, a limited number of farmers use new irrigation technologies like motor pumps for dewatering, pedal pumps, irrigation water pump generators, and traditional sumps. Irrigation pumps are only used where surface water flow is limited. However, this is not a common practice for poor farmers as their ability to afford irrigation pumps is very limited compared to commercial-oriented or affluent farmers. Water cans and baskets are mainly used for irrigation in small plots, usually by women and children. Relying on high irrigation technology is considered impossible as most farmers could not afford it due to limited financial and social capital. Therefore, localized physical assets are mainly used to enhance irrigation in the study area.

4.4. The role of SSI systems in enhancing smallholders' resilience to food security

As described earlier that Niger is located in the Sahel region – a region with high vulnerability to climate change, prolonged droughts, sporadic rainfall, and increasing desertification (Adisa, 2020). Desertification, prolonged droughts, and sporadic rainfall are not new phenomena in the study area and Niger as a whole. People have lived and survived this critical condition for many years by creating different coping mechanisms and adaptation strategies. How do individual smallholder farmers and the community build resilience to food security amid climate change? SSI is one of the historical survival strategies used to ensure the availability of households' food and income. Informal, farmer-initiated and farmer-managed SSI remains one of the major survival strategies against harsh weather and climatic condition for the majority of the smallholder farmers in the study area and Niger as a whole and has enabled households to improve food security. SSI improves local food security in two main ways.

Firstly, SSI allows smallholder farmers to grow various food crops, which helps them during difficult times, particularly during the dry season. Since smallholder farmers grow both food and high-value cash crops, it is easy to acquire enough food (though, in some cases, not necessarily satisfactory) to sustain their families. In addition, SSI systems enable rural farming households to obtain nutritious food, especially vegetables and some short-term grains, which offer nutritional supplements and improve people's health status. During the interviews, farmers reported that engagement in SSI helps them get a more balanced diet and more than two meals every day, which helps improve their health and immunity and also reduces malnutrition, especially for children. As one respondent insisted:

> Ever since I started engaging in small-scale irrigation, food deficit has remained a daytime dream in my house. Through small-scale irrigation, I can get varieties of food directly from my own farm. Those that cannot be obtained directly from my farm can be bought from the surrounding shops using the money I get after selling crops, especially vegetables.

From the above quotation, it is clear that farmers who engage in SSI reduce the chance of being food insecure. This particular finding is consistent with that of Ahmed (2019) and Jambo et al. (2021), who found that in Ethiopia, households that engage in SSI have

a higher chance of being food secure and obtaining a balanced diet than their counterparts who do not engage in SSI.

Secondly, SSI was reported to increase the purchasing power of households engaging in a production system for foodstuff. Households engaging in the SSI reported increasing income and strong purchasing power, particularly during the dry season. Among the horticultural crops that give farmers high income is onion. Farmers from the study area enjoy a good onion market, particularly when trading with outsiders (outsiders here means merchants from neighbouring countries like Ivory Coast, Benin, Togo, and Ghana, to mention a few). Depending on the season, these merchants from abroad pay a higher price to the smallholder farmers than the domestic market. The good price of onions and other crops helps smallholder farmers improve their income, increasing their purchasing power for food and other necessities. Besides, the vitality of SSI agriculture was reported to be higher than that of rainfed agriculture. Production per unit area was reported to be twice or more than twice as compared to rainfed agriculture, which usually gives farmers low yields or, in some cases, nothing due to prolonged droughts. Nevertheless, if appropriate support from external agencies like the government and other development practitioners is given, smallholder farmers' resilience to food security and climate change could be much higher.

5. Discussion

By using the notion of indigenous knowledge, this study points out how smallholder farmers from remote and poverty-stricken rural areas from the global south use their limited resources, knowledge and technologies to build resilience to food security amid climate change. The study shows how smallholder farmers use their internal agency to establish informal, farmer-initiated and farmer-managed SSI agriculture to build resilience to food security amid climate change. In the context of Niger, food insecurity is still one of the major development challenges and climate change, droughts, rapid desertification, loss of soil fertility, erratic rainfall and devastating flash floods limit production and result in poor performance of the agricultural sector (Ado et al., 2019). This is also a case in many other SSA countries like Madagascar, where climate change has resulted in a temperature rise, a fall in farm production of more than 50%, and increased food insecurity and malnutrition (Nematchoua et al., 2018). Besides, limited and unevenly distributed and uneasily accessible water resources make smallholding farming, which entirely relies on rainfall, much more difficult and complicated (Zakari et al., 2014). To respond to these shocks, vulnerable rural smallholder farmers' households use different strategies, including both negative and positive survival strategies. For the negative survival strategies, smallholder farmers use different strategies like usury, pre-harvest sale of crops, and land sale. Positive survival strategies include livelihood diversification – crop diversification and off-farm livelihood diversification and migration, especially rural-to-urban migration of the young generation. Diversification into agriculture also involves engagement in the agro-pastoral system. Ado et al. (2019) found that rural households that 'obtained their livelihood from both agriculture and livestock (agro-pastoral systems) are more resilient' than the households relying on either of the two.

SSI agriculture is also highly cited as an important climate change coping and adaptation strategy among smallholder farmers in Niger and many other countries from the Global South (Lefore et al., 2019; Xie et al., 2021). It also remains one of the profound tools to combat hunger and malnutrition, reduce rural poverty and improve households' welfare in many developing countries, particularly amid the climate change era (Ndimbo et al., 2021; Zhang et al., 2021). Many studies have found a significant correlation between SSI agriculture, local food security, and rural poverty reduction (see, for example, Adeniyi & Dinbabo, 2020; Ahmed, 2019; Balana et al., 2020; Zhang et al., 2021). This study also found that SSI agriculture improves households' food security by ensuring the availability of various foods, especially during difficult times, and by increasing households' purchasing power. In this case, smallholder farmers are not necessarily producing staple food crops. Instead, they might opt to produce high-value horticultural crops like onions, which give them high income and hence increase their purchasing power in food and other necessities.

The SSI system in the study area is mainly informal, farmer-initiated, and farmer-managed, with limited or sometimes no support from external agencies like the government and other development partners, such as international organizations and non-governmental organizations (NGOs). Anil et al. (2020) refer to this situation as community-based self-help in agriculture,

where farmers use their limited resources and knowledge to invest in SSI agriculture to build resilient livelihoods amid the growing climate change crisis. Other scholars call it farmer-led irrigated agriculture (Lefore et al., 2019). This kind of initiative is not a new phenomenon in developing countries since, for many decades, smallholder farmers have developed different strategies to respond to natural and human-induced challenges to improve their welfare. However, farmer-led irrigation development is less recognized and appreciated in development policies (Woodhouse et al., 2017). In response to climate change-induced shocks, for example, smallholder farmers have found themselves adopting SSI agriculture, among other strategies, to ensure food availability and income at the household level (Rankoana, 2022; Tofu et al., 2022). Due to limited external support, farmers mainly rely on indigenous knowledge and technologies to grow various irrigated crops to enhance food and income security. However, farmer-led irrigation development in many countries in the Global South, particularly SSA, is highly neglected by policymakers, and data on it is rarely available (Woodhouse et al., 2017). This study's findings revealed that government support for SSI agriculture is mainly limited to the areas along the Niger River basin. In contrast, the interior and poverty-stricken areas of the country, like the Tamaské rural community, are always neglected. In this context, farmers' individual or collective efforts remain crucial in establishing SSI systems and building resilience to food security and climate change.

As noted earlier that one of the key features of informal, farmer-initiated, and farmer-managed SSI systems in SSA and Niger, in particular, is that of relying on local knowledge and technologies. The application of indigenous knowledge and technologies is considered more cost-effective and appropriate based on the specific local context, even though their application to solving the problem of water scarcity amid global climate change is still limited. This is, however, a common problem for the majority of the smallholder farmers in many developing countries when it comes to the adaptation of irrigation technologies, particularly those that solve the problem of water scarcity resulting from climate shocks (Van Der Wijngaart et al., 2019; Wainaina, 2021; Zarei et al., 2020). Nevertheless, the situation is somehow different in some other parts of the Global South. In some Asian countries, for example, smallholder farmers deal with water scarcity by adopting simple and modern irrigation technologies, the operational costs of which are usually subsidized by the states (Mutambara et al., 2016). This is not the reality in many countries from SSA like Niger, where the government's ability to subsidize SSI systems is limited.

The majority of the poor farmers were unable to afford the costs of drilling wells for irrigation and buying modern irrigation facilities like irrigation pumps due to high costs, and the government's ability to subsidize operational costs is limited due to poverty and lack of clear mechanisms to reach out the intended smallholder farmers. Besides, even if farmers could manage to drill modern irrigation wells, the lack of electricity connection by the national grid in many rural areas of Niger, as in many other sub-Saharan African countries (Haulle & Ndimbo, 2024), coupled with high connection and billing prices, would force them to use diesel generators whose operational costs also remain high, unaffordable to the smallholder farmers and environmentally unfriendly. With more than 80% of Niger's population living in rural areas, for example, only 8% have access to grid electricity (Bhandari et al., 2020). This implies that efforts to invest in modern high-tech irrigation infrastructures will be constrained by limited access to sufficient and affordable electricity, let alone other factors like limited financial capital and technical skills. Nevertheless, this study emphasizes that with limited SSI infrastructure and financial capacity in the Global South, more focus on low-cost input in adaptive technology and its dissemination will be able to multiply those local potentials. In this case, appreciation of resilient trajectories from within the smallholder farmers themselves should be the starting point for any grassroots development intervention.

6. Conclusions

This study has explored the value of indigenous knowledge in enhancing smallholder farmers' resilience to food security amid climate change. To achieve this broad objective, the study has built on the case of informal, farmer-initiated, and farmer-managed SSI agriculture in Niger to explore how smallholder farmers from remote and poverty-stricken rural areas use informal SSI systems to build resilience to food security and climate change. From the study's findings, individual and collective actions are the basic conditions for developing SSI systems. This study finds that SSI could easily be initiated and

multiplied with farmers' agencies if the farmers could select more appropriate technology and cooperation mechanisms without demanding lots of external investment. The findings imply that (1) There is always the potential for SSI initiation if exploring indigenous knowledge historically and timely; (2) The development intervention paradigm for enhancing smallholders' resilience to food security facing climate change challenges could take peer learning among smallholder farmers as a turning point for transition; and (3) In the context of limited financial support from the government in most areas of the Global South, the policy focus should be on the promotion and dissemination of simple and root-based technology that does not require much external support. It is argued that the effective implementation of this socially innovative strategy would not only lead to the 'satisfaction of interests; effective socio-political arrangements; and empowerment' of the engaging smallholder farmers (Castro-Arce et al., 2019) but also attract more farmers to engage in SSI, improve their welfares and build resilient livelihoods.

Nevertheless, to effectively achieve the objectives of the 2030 agenda for sustainable development, internal agency alone is not enough to make SSI a viable tool to address food insecurity and improve rural welfare amid climate change. To ensure that no one is left behind in eradicating hunger amid climate change and achieve the second goal of sustainable development, the government and other development stakeholders should deliberate efforts to improve SSI to support investments in SSI in neglected, remote and poverty-stricken areas. The support should range from more soft support, such as knowledge sharing and cooperative capacity development, to more complex ones, particularly setting up irrigation infrastructures like drilling modern wells and ensuring the availability of cost-effective irrigation facilities and technologies. Besides, the availability of sufficient and affordable energy to run irrigation machines like solar pumps instead of motor pumps or diesel generators, which require high operational costs and are environmentally unfriendly, is highly recommended. The support should also aim to ensure farmers' access to the stable market and control middlemen who reap what they do not sow from the smallholder farmers. In this case, the support for setting up modern storage facilities to avoid post-harvest loss like that of onions should be given higher priority, and farmers should be linked with market opportunities to avoid intermediaries. Finally, the formalization of land ownership is also one of the transitional pathways to building resilient rural livelihoods as it will help the smallholder farmers to use the land as collateral to obtain credits from formal financial institutions instead of the current mechanisms used by farmers to rent money from informal financial institutions or rural bourgeoisie which in many cases results in farmers loss of land due to failure to repay the high-interest loans. All these solutions could not be driven through indigenous knowledge alone; instead, the integration with external efforts through the so-called neo-endogenous efforts would enable more smallholder farmers to engage in SSI systems, reduce vulnerability and make it a tool for building resilience to food security amid climate change and enhancing sustainable and resilient rural livelihoods.

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