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Participatory diagnosis and development of climate change adaptive capacity in the groundnut basin of Senegal: building a climate-smart village model

Diaminatou Sanogo[1*], Badiane Yacine Ndour[2], Moussa Sall[3], Katim Toure[4], Mouhamadou Diop[1], Baba Ansoumana Camara[5], Ousmane N'Diaye[6] and Djibril Thiam[7]

Abstract

Background: Up to now, efforts to help local communities out of the food-insecurity trap were guided by researcher (or other actors)-led decisions on technologies to be implemented by the communities. This approach has proved inefficient because of low adoption of the so-called improved technologies. This paper describes the strategic approaches to the development of a climate-smart village (CSV) model in the groundnut basin of Senegal. A CSV model is a participatory integrated approach using climate information, improved context-based technologies/practices aiming at reaching improved productivity (food and nutrition security), climate resilient people and ecosystem and climate mitigation. In this study, participatory vulnerability analysis, planning adaptation capacity and participatory communication for development were implemented, putting people affected by the impacts of climate change (CC) at the center of the approach. Four interdependent groups of activities/domains, namely—local and institutional knowledge, use of climate information services, development of climate-smart technology and local development plans, were covered. It was emphasized, how all this taken together could create improved livelihoods for women, men and vulnerable groups.

Results: The approach made it possible to involve local people in the decision-making process for the development of their adaptation capacity to CC. It also helped to set up an overall land management process by identifying and addressing environmental (sustainable resource management, ecosystem resilience) and socioeconomic (institutional organization, empowerment, poverty alleviation and food security) challenges. A monitoring survey revealed that farmers appreciate well this participatory approach compared to previous top-down approach in that the former allow them to own the process. Also determinant drivers of adoption of the technologies were identified.

Conclusion: Scaling this community development model in sites with similar climatic and socioeconomic conditions could help in contributing toward achieving food security in rural areas at wider scale because of better enthusiasm and engagement from rural farmers to pursue solution to their constraints taking into consideration constraints posed by climate and more need based and tailored advisory services.

Keywords: Adaptation, Climate-smart technologies, Resilience, Sustainable development

*Correspondence: sdiami@yahoo.fr
[1] Centre National de Recherches Forestières (CNRF/ISRA), BP 2312, Dakar, Senegal
Full list of author information is available at the end of the article

Background

In Africa, 70–80% of hunger and poverty are concentrated in rural areas [1]. Climate change adds an extra burden to this situation that is already severe with disastrous consequences on food security for the populations [2]. Thus, rural communities, particularly those in the Sahel, who live in an environment that is already fragile, are more vulnerable because of the importance of natural resources and rain-fed agriculture in their economies [3]. Senegal, particularly the agro-ecological zone of the groundnut basin, is in this situation where 70% of the population depends on agriculture and livestock and where the natural vegetation is replaced by crops on most of the land [4] with the resultant diminishing soil fertility. In this area, agriculture, mainly of rain-fed type, is heavily dependent on agro-climate parameters such as rainfall, temperature, sunlight and wind that experience significant variations over the years [5]. This amplifies the vulnerability of rural populations that are in a vicious cycle of poverty. In the face of this situation, major projects have been implemented in Senegal to promote adaptation through the dissemination of climate-smart technologies and practices. Despite these efforts, the food security situation is still precarious and even critical for the rural population. One of the reasons for this situation is that many different planning approaches and tools are used leading often to low participation of the local populations in the assessment of their own ability to adapt to climate change [6]. In fact, the degree of participation of the rural population in the planning, monitoring and evaluation of adaptation capacities was often incomplete and inadequate. In many cases, the populations were not involved in decision making. Participation was often limited to analyzing vulnerability and giving researchers the choice to determine and plan adaptation actions and choose tasks to be undertaken by communities. Consequently, there is a lack of consistency between the situation of vulnerability and adaptation actions [6]. Recently an holistic approach called climate-smart agriculture (CSA) is being promoted and consists in the use of climate information and context-based technologies and practices with the aim to improve productivity (food and nutrition security), increase resilience of the people and ecosystems (adaptation) and reduce greenhouse gases emission/sequester carbon when possible (mitigation) [7]. However, the rate of adopting climate-smart technologies and practices remains very low [8]. The linear approach, which is still present in a large number of programs and institutions, has been criticized for its monopoly on production of knowledge by researchers [9] and its rigid view of innovation [10]. The importance of mainstreaming technological innovation in policy, organizational and institutional innovation in agricultural development research projects was called for [8]. In this study we hypothesized that the actual involvement of men, women and vulnerable groups in the use of diagnosis, planning, monitoring and evaluation tools can sustain individual, organizational, institutional and policy behavioral changes in order to adapt to climate change and adopt climate-smart practices. This paper describes the process of mainstreaming social and environmental components into development of a climate-smart model village, using participatory tools for analyzing vulnerability, planning adaptation activities and communication for development. This approach is thought to be suitable for sustainable human development processes especially in sub-Saharan Africa taking into consideration the fact that human behavior is determined by complex and multifaceted relations of individuals, families and communities with the environment, geography, history, culture, politics, the economy and religion [11]. The paper also assesses local perception of the current participatory approach as compared to previous top-down approach.

Methods

Study area

This study was conducted in the Kaffrine Region, intervention site of the Climate Change, Agriculture and Food Security (CCAFS) program in Senegal. The priority intervention area is a square block of 30 km × 30 km (Fig. 1) [12]. This area covers about fifty villages in five rural municipalities. It concerned more specifically the Ndiognick Rural Municipality, Ngouye and Daga-Birame Villages, Kaffrine Division and present Kaffrine Region situated between longitudes 15°86 W and 14°58 E and latitudes 14°74 N and 13°74 S [13].

Rainfall in the area varies between 600 and 700 mm. The hydrographic system of the region consists of the Saloum branch, temporary ponds and small valleys fed by rainwater. These are water points used as drinking water for livestock, but they dry up in the dry season [13]. Vegetation is of Savannah grassland type where only few trees and shrubs are encountered, mainly in the north of the Kaffrine Region, in areas with very shallow (encrusted) or very dry soil [14]. Species such as *Combretum glutinosum*, *Combretum nigricans* and *Guiera senegalensis* are the dominant ligneous component. The region had 566,992 inhabitants in 2013 with a density of 50.6 inhabitants per km^2 which is lower compared to national average of 69 inhabitants per km^2 [15]. Agriculture, livestock, forestry, handicrafts and trade are the main activities in the region. Pertaining to agriculture sector at the whole nation level, in the season 2010–2011, the Kaffrine Region was ranked second cereal producer with 221 038 tons and first groundnut producer with 23.48% of national production [16]. However, due to

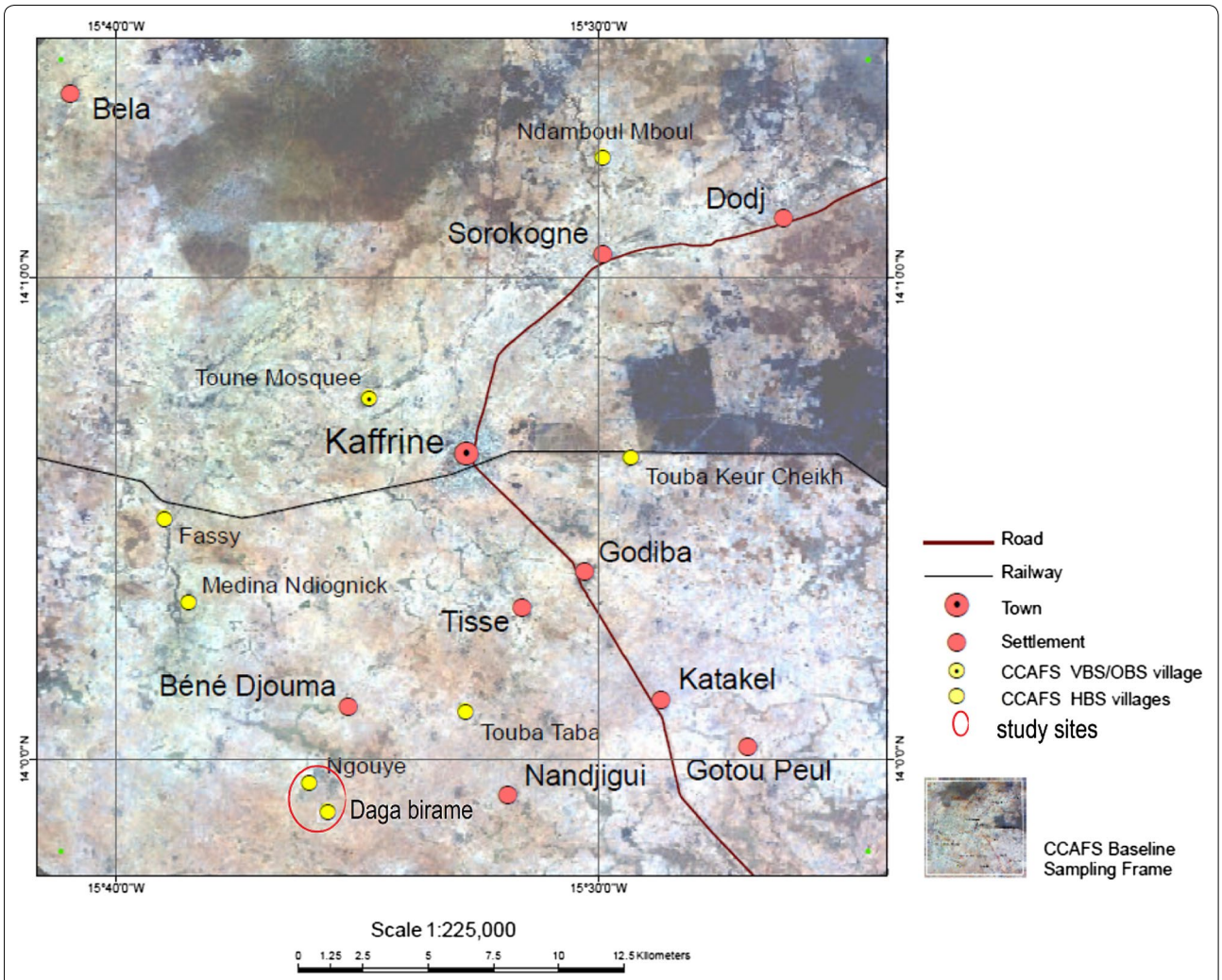

Fig. 1 Location of the two study sites (Ngouye and Daga-Birame Villages) in Kaffrine Region, Senegal

soil depletion and decreasing rainfall, crop productivity is declining [17]. In recent years, livestock, an also dynamic and vital economic sector in the region, ranks second after agriculture.

Data collection

The methodology of this study is based on the Participatory Communication for Development (PCD) approach. PCD is defined as "a planned action, based on the one hand on participatory processes and on the other hand on media and interpersonal communication, which facilitates dialogue among various actors" [9]. The rationale for choosing this tool is that it helps facilitate community participation (men, women and vulnerable groups) in their own development initiatives through the use of various communication strategies. Here, the expression "community participation" does not refer to the mere participation in the activities described by other actors, but participation in decision making on activities to be undertaken and goals to pursue. This study gathered 76 agro-pastoralists to whom the different tools were explained. They were later on separated into groups of men (37) and women (39) for the practical use of the tools. The process included four main interrelated phases which are: problem definition, planning, intervention/experimentation and evaluation. It develops continuously through each of the landmark stages, through interactions between actors and members of the community. For the first two phases which correspond to diagnosis and planning, data were collected using participatory vulnerability evaluation and adaptation capacity to climate change tools. They are extracted from the adaptation capacity planning and monitoring and evaluation toolkit (TOP-SECAC) [18]. These tools help to start from analyzing the situation of vulnerability and adaptation capacity to the impact of climate change on a community,

in order to develop a vision, identify an action plan for building adaptation capacity of the populations and institutions and, finally, identify partners that can contribute to the implementation of adaptation actions. The tools used are:

- Tool 1: Analysis of vulnerability and adaptation capacity to climate change. It consisted in participatory drawing of a map on livelihood resources and requesting farmers to identify three most important climate hazards and locate them in the territory placed under their management. Then a vulnerability matrix was developed to analyze the perception of members of the community concerned about the level of influence of climatic hazards on main livelihood resources. The groups were asked to give a score to the impact of the different climate hazards on their resources (0 = the hazard has no impact on the resource; 1 = very low impact; 2 = low; 3 = average; 4 = strong; 5 = very strong). Finally, a matrix of adaptation strategies was used to help identify and analyze (current and future) adaptation strategies. It included the level of importance of main livelihood resources in the implementation of the said strategies.
- Tool 2: The CRiSTAL (Community-based Risk Screening Tool—Adaptation and Livelihoods). Use of CRiSTAL helped us to input the data collected by Tool 1 to obtain various crossed tables that linked—climate hazards and their impacts on key resources and adaptation strategies of communities—and proposed actions and their influence on the resources most affected by climate hazards on the one hand, and on the other hand, the influence these actions have on the most relevant resources for adaptation.
- Tool 3: Vision-Action-Partnership (VAP). This tool enabled community members of the study area to make future projections in a context of climate change. In a participatory manner, community members defined the ideal or desired situation in which they would like to be, despite the existence of climate hazards. The definition of the ideal situation was based on various impacts of climate hazards observed. They then identified actions they had to implement by themselves and partners to whom they have made specific requests. Actions identified were later prioritized by communities in meetings. The defined actions were categorized by the researchers and put in the framework of the CSV following the four (4) components of the model which are 1—development of climate-smart technologies and practices, 2—climate information services for improved climate risk management, 3—local development planning and 4—strengthening local institution and knowledge sharing. In the current paper, only major activities put in place will be given.

Finally, the evaluation phase concerned capitalization, dissemination of results and self-evaluation of the impact of activities jointly carried out by local stakeholders, researchers and other actors. Moreover, a survey was conducted to evaluate the perception of the stakeholders on the most significant activities of the project that induce adoption of technologies and the approach of the project notably in comparison with previous top-down approaches used by other projects in the areas. In total, 25 people from which 20 farmers (10 men and 10 women) and 5 technicians (a forester, an agriculture extension agent, 2 decision makers and a research assistant), all actively involved in the project, were surveyed.

Results and discussion

Analysis of vulnerability and adaptation of the communities of Ngouye–Daga-Birame to climate hazards

Matrix of vulnerability of livelihood resources

The three main hazards said, both by men and by women, to mostly affect livelihood resources were strong winds, flooding and drought (Table 1). For men the hazard that affects the resource most was drought, while for women it was strong winds.

Analysis of the assessment of the level of influence of hazards on livelihood resources by local communities on a scale from 0 to 5 shows that for men and women, it was the component "financial resources" derived from the sale of agricultural, livestock and market gardening products which are most affected by various climate hazards. On the contrary, physical resources (drilling, health post, school) are thought to be less affected by climate hazards.

Analysis of the impacts of climate hazards and related adaptation strategies

Table 2 focuses on analysis of the impacts of climate hazards and related adaptation strategies. For both men and women, the impacts of winds observed are fires spreading into homes, spread of disease and habitat destruction (removal of roofs). The responses described by these groups of men and women are recourse to firefighters, building houses using cement bricks and reforestation. But because of firefighting stations being far from the village, the lack of resources to build and lack of knowledge on tree planting, these strategies were not feasible. Women specifically mentioned infertile land as a consequence of strong winds and recommended the use of fertilizer and the promotion of Farmer-Managed Natural Regeneration (FMNR) to address the issue. They also pointed out that inadequate financial resource, the lack of

Table 1 Local perceptions of the impact of the different climate hazards on livelihood resources at Ngouye and Daga-Birame villages in Kaffrine Region, Senegal

	Strong winds		Flood		Drought		Total score given by the different groups for the combined effect of the different hazards		
Resources/gender	**M**	**W**	**M**	**W**	**M**	**W**	**M**	**W**	**B**
Natural resources									
Farmlands	4	4	5	5	2	3	11	12	23
Rainwater	2	–	0	–	5	–	7	0	7
Livestock	3	2	–	–	5	4	8	6	14
Trees	–	5	–	4	–	–	–	9	9
Physical resources									
Drilling	0	0	0	0	3	0	3	0	3
Health post	1	4	–	–	0	0	1	4	5
School	1	–	4	3	0	0	5	3	8
Financial resources									
Incomes derived from agricultural products	5	4	4	4	5	3	14	11	25
Incomes from small livestock	2	3	–	4	5	–	7	8	15
Incomes from market gardening	–	3	–	0	–	5	–	8	8
Trade	3	–	2	–	5	–	10	–	10

The numbers in the table are the score given by the different groups (men and women) to the impact of the hazard on the specific resources

"–" means that the group did not mention the resource or the hazard as important. *M* men, *W* women and *B* both genders

0 the hazard has no impact on the resource, *1* very low impact, *2* low, *3* average, *4* strong, *5* very strong

Table 2 Assessment of the impacts of the different climate hazards, suggested adaptation strategies and factors preventing the adoption of these strategies, as perceived by farmers in Ngouye and Daga-Birame villages in Kaffrine Region, Senegal

Group	Impacts	Adaptation strategies	Factors preventing the adoption of the alternative strategy
Strong winds			
Men and women	Fire spreading into homes	Call firefighters	Remoteness of the fire brigade
	Spread of diseases	Build brick houses with slabs	Lack of means
	Habitat destruction (removal of roofs)	Reforestation	Inadequate awareness on the use of plant produced
Women	Infertile land	Fertilizers Promotion of FMNR	Insufficient financial resources and lack of partners Lack of resource management rules
Men	Wind erosion	Windbreaks	None
Flood			
Men	Loss of animal life	Build brick shelters	Lack of means
	Human and animal health	Use modern medicine/construction of a health post	Lack of partners
Women	Destruction of crops	None	None
	Destruction of yields	None	None
Men and women	Destruction of huts	Build brick houses	Lack of means
Drought			
Men	Poor harvest	Establish food stocks	Bad rainy season
	Resurgence of diseases	Strengthen mutual health insurance	Financial resources
	Decline in animal productivity	Build fodder reserves	Lack of means
Women	Decline in market gardening productivity	Improved watering means (pump, installing solar panel)	Lack of financial partners

partners and the lack of resource management rules are factors preventing the adoption of this alternative strategy. Windbreak was mentioned as adaptation strategy to control wind erosion. Although local communities did not mention any specific factor that could impede this, it could be thought that if the issue of lack of resource management rules was solved, the relic of vegetation that surrounds the village could be restored and play the role of windbreak. With regard to flood hazard, its potential impacts are described by men as loss of animal life and health issues for human and animals. Responses proposed are building houses using cement bricks and making use of modern medicine. The lack of funding and partners are reported as factors impeding the adoption of these strategies. For women, there are specifically the destruction of crops and reduction of yields and no strategy has been developed by these women to adapt. Both groups were unanimous on the destruction of homes due to flooding with building houses using cement bricks as an adaptation strategy proposed by the community, but lack of resources is a factor impeding the adoption of this potential solution.

For drought, impacts observed for men are poor harvest, resurgence of diseases and decline in animal productivity. Responses described are, respectively, the establishment of food stocks, strengthening mutual health insurance and establishment of fodder reserves. Bad rainy seasons and the lack of funds are the main limiting factors of these solutions. For women, the impact observed is decline in market gardening productivity. The response described by this group is the improvement of means of pumping water. The lack of technical and financial partners is a factor limiting the adoption of this alternative.

Vulnerability analysis highlights strong winds, floods and drought as the main climate hazards in the study area for both men and women. These results corroborate those of previous studies. Indeed, Somda et al. [6] reported the same climate hazards, their impacts and adaptation strategies in five communities in the CCAFS intervention area in Burkina Faso. Women and men have divergent views about the impacts of these hazards. According to Somda et *al.* [6], the impacts observed by one or the other sex are related to livelihood resources that are available to and used by them.

Financial and technical resources, partnership, local institutions, education, skills, information and communication are important factors for adaptation to the impacts of climate hazards. In this study, farmers identified lack of means, financial resources and partners as factors preventing the adoption of adaptation strategies. Though communities know effective and sustainable adaptation strategies against the impacts of climate hazards, they do not always have all the required capacities to adopt them. Ouedraogo et al. [19] highlighted that identifying important adaptation factors is not good enough to guide adaptation action if factors limiting the implementation of adaptation strategies are not analyzed and properly addressed. Some adaptation strategies suggested by the local people (calling the firefighters for fire spreading) are not really relevant because of the remoteness of the area. Putting in place local fire fitting committee may prove to be a better solution.

Mainstreaming gender in the process of assessing vulnerability and livelihood resources also helps to identify strategies that can be termed neutral in that they apply to both women and men. The gender-based analysis therefore has the advantage of developing capacity building actions geared toward women or men or both.

Planning, monitoring and evaluation of adaptation capacity to climate change

Planning adaptation capacity to climate change for Ngouye–Daga-Birame communities done on the basis of information derived from participatory analysis of vulnerability and adaptation strategies is mentioned in Table 3. It is about the future vision, priority actions and identified partnerships. Analysis of the vision defined by communities over a period of 10 years from identified problems shows that it relates to many domains: For crop production, the aim was to reach sufficient food for consumption as well as surplus stocks. Specifically, eradication of pest and diseases, control of water erosion and increased income generation from market gardening were cited. For livestock, increased number of animals, improved health conditions and conformation (shape and structure) were aimed for. There was also mention of reducing livestock deaths due to flooding. Regarding human, physical (house, road), financial and social resources, the community also wished to eradicate diseases related to drought and rainfall breaks, build cement brick houses and tarred road, have better access to financial resources and reduce poverty and, finally, reach dynamic, autonomous, well-structured and functional organizations and strengthened partnership. The definition of communities' vision, as detailed above, led to the identification of specific actions to be undertaken. Although community engagement was in the frontline, a key condition to getting an operational CSV model appeared to be the building of a strong partnership that will allow implementation of the different actions in an integrated manner. This partnership must include research and extension services, meteorological services, non-governmental organizations (NGOs), private sector, local decentralized authorities and community organizations.

Table 3 Suggested/needed interventions to pursue desired future despite the impacts of climate hazards on community resources, support requested and needed partnerships, according to the communities of Ngouye and Daga-Birame villages in Kaffrine Region, Senegal

Impacts of the different climate hazards on community resources	Desired future (10 years)	Actions needed/suggested by the communities	Support requested and partners targeted by the communities
Natural resources			
Poor harvests	Communities' crop production is enough to feed themselves well and keep surplus stocks	Organize producers Revitalize partnership with projects Diversify sources of production and improve management (savings, behavior change) Acquire improved and adapted seeds Restore soil fertility (FMNR, compost, etc.) Develop counter-season crops with emphasis on the construction of ponds and digging of wells	Agricultural and meteorological council (CCAFS) Improved seeds fertilizers (CCAFS, State, PAFA) Farming material (State, PAFA, CNCAS) Capacity building (ISRA, PAFA, WV, EGABI, ANCAR, SDDR) Enhancement of forest resources (fruits, firewood) Warehouse and storage (CRS, WV, PAFA, State, CR)
Decline in livestock production	Increased number of animals, their health and their conformation improved	Feed from unharvested by-products Improve animal food rations Stabilized livestock Use of veterinary services and improved breeds	Financial credits (financial partners) to rural council strengthen animal production activity Provision of veterinary services (private or State) Stem crusher—ISRA (training), Ministry of Livestock Training—EGABI, ANCAR, ISRA, livestock service
Destruction of crops due to parasitism	Eradication of parasites from the locality	Introduce the request to the DPV Treat using neem, salt and chemicals in infested areas. Fight against Striga through application of small animals' dung	Monitor DPV to consider pests Capacity building on techniques to fight against pests (DPV, ANCAR)
Destruction of farmlands due to erosion (water and wind)	Controlled water erosion Better management of farmlands to avoid erosion	Raise awareness of the populations Build small dikes Dig small water storage basin Windbreaks (shield to reduce the force of the wind) with adapted species (Eucalyptus, Faidherbia, etc.) Promote FMNR and reforestation Organize the monitoring of plantations	Soil conservation and restoration measures Capacity building in making stone barrages or gabions (ISRA, rural council , forestry, ANCAR) Support local nurseries with seeds and water provision—forestry, WV, CR Training—forestry, ANCAR, WV, ISRA
Destruction of harvests and post-harvests due to parasitism	Total eradication of parasites	Chemical treatment of crops Wind breaks to protect crops Regular stock control	Warehouse (WFP PAFA, ANCAR, State) Capacity building (ANCAR, DPV)
Decline in market garden production	Increased incomes derived from market gardening	Give more land access to women for establishing market gardening plots More access to resources to hire labor	Improved means of pumping wells Phyto-therapy (ISRA/Agricole, ANCAR, WV)
Livestock death	No more livestock death due to flooding	Construction of brick enclosures Fence houses	Financial support (grants) Housing loans—PAMECAS, CMS, CNCAS
Human resources			
Resurgence of diseases due to drought and rainfall breaks	Total eradication of diseases related to drought and rainfall breaks	Be sheltered from winds Prevention against diseases Improving children's nutrition	Strengthen the health unit to better treat diseases caused by drought Fruit trees for diversifying the starchy diet Program to improve child nutrition (PRN and CLM)

Table 3 continued

Impacts of the different climate hazards on community resources	Desired future (10 years)	Actions needed/suggested by the communities	Support requested and partners targeted by the communities
Physical resources			
Destruction of trails	Tarred roads in the place of trails	Advocacy with authorities	Decentralized cooperation (PAFA)
Destruction of houses	All houses built with bricks	Savings for construction Advocacy for rural housing Replace stubble with zincs then with terraces	Construction of rural houses Financial support (grants) Housing loans—PAMECAS, Senegal Mutuel Loan CMS, CNCAS
Financial resources			
Lack of appropriate financial scheme	Have better access financial resources to construct bricks houses	Diversify sources of income (trade, breeding, etc.) Save on income Mutualization/cooperative of resources/means	Financial institution (CNCAS, ACEP, CMS, PAMECAS) for savings and credit financing
Increased poverty	Poverty alleviation	Diversify sources of income (trade, breeding, etc.)	Access to credits (CMS PAMECAS, ACEP) Organizational dynamics and training (ISRA, ANCAR)
Social resources			
Weak functioning of existing institutions/organizations	Dynamic, autonomous, well-structured and functional organizations and strengthened partnership	Share information between various organizations Strengthen community actions Seek a consultation forum Establish village organizations	Establishment of a framework for meetings (headquarters, executive office)—CR, State, WV, PAFA Training—ISRA, WV

ANCAR Agence nationale de Conseil agricole et rural (national agency for rural and agricultural council), *CR* Commune Rurale (rural commune), *CMS* Crédit Mutuel du Sénégal (Senegal Mutuel Loan), *DPV* Direction de la Protection des Végétaux (Direction of Plant Protection), *EGABI*, *CNCAS*, *ACEP*, *CMS*, *PAMECAS* Financial agencies, *FMNR* Farmer-Managed Natural regeneration, *ISRA* Institut Sénégalais de Recherches Agricoles (Senegalese Institute of Agricultural Research), *PAFA* Program Supporting Agricultural Sectors, *SDDR* Service du Développement Rural (County Rural Development Service), *WV* World Vision

Initiatives/activities undertaken in the Ngouye–Daga-Birame climate-smart village

The initial diagnosis step prompted initiatives and activities from the communities that were seen as needed to address the issues raised and adapt to climate change. Often, some initiatives from the communities appeared unsuited mostly because they were not well informed or aware of options available or proved efficient elsewhere. In such situations, partners got involved in the discussions and provided guidance. Final decisions made by the communities and activities undertaken were categorized in one of the four components of the CSV framework as follows:

Development of climate-smart technologies and practices

Apart from the initial diagnosis and definition of the future vision and the constraints which guided identification of action decided under the component of CSA technologies and practices development, the process was also aided by an interfarmers exchange visit organized for the Ngouye–Daga-Birame community to Linguere-Dahra, a drier environment, so that communities could learn how their fellows were thriving in conditions that were worse than the one they had back home. All these provided guidance on actions to be undertaken. The resulting technological solutions are expected to address the constraints identified in the diagnosis step and contribute to the desired future vision. Under the current component, actions included, among other things: (1) *the use of demonstrations on drought-tolerant crop varieties* selected on the basis of the seasonal forecast information, compared to traditional varieties; (2) *combined soil tillage fertilizer micro-dosing and Farmer-Managed Natural Regeneration (FMNR) for Integrated Soil Fertility Management* (ISFM); (3) *fruit tree planting for improved vegetation cover and income generation with improved cultivars of five tree species* (*Ziziphus mauritiana, Adansonia digitata, Tamarindus indica, Psidium guajava and Annona muricata*); (4) gardening activities by women for nutritional security and income generation; (5) processing of Non-Timber Forest Products *(NTFP)*, notably baobab fruits into powder, for generating income and contributing to nutrition needs. Under this component, the issues of soil degradation, poor harvests, poverty and lack of financial means are addressed to improve people resilience. The income generated could serve to purchase food provisions and to rescue community members during poor harvest years. It could also serve to invest in resilient sustaining activities. Consideration of the local constraints, particularly the one posed by climate, drives rapid change in farming practices as observed by Ouedraogo et al. [20].

Climate information services for improved climate risk management

Knowledge on local climate conditions, through seasonal forecasts, information on dates of the start and end of the rainy season, and short-term forecast, may allow farmers to better synchronize their farming activities (and other livelihood activities) to climate variability and improve their resilience to climatic shocks identified during the diagnosis step. Since 2011, a local multidisciplinary working group (made of various decentralized institutions, local farmers and private sector organizations, and the media) established by the national meteorological services, has been sharing climate and weather information with farmers through training workshops (at the beginning of the season), mobile phones and local radios. Subsequently, farmers from the Ngouye–Daga-Birame innovation platform (IP see below) who attend the workshop, also relay the climate information to their fellow farmers through the IP. In addition, some farmers in the different neighborhoods of Ngouye and Daga-Birame receive climate information on their mobile phones and share it with others. Recently, to add value to ongoing initiative on climate services, a new approach, Participatory Integrated Climate Services for Agriculture (PICSA), has been introduced. This approach helps farmers long before the season starts, to match their production and other livelihood options to local climate features (derived from historical climate records) and individual circumstances, and subsequently use other/usual climate information services (seasonal and short-term forecasts and warnings) to adjust their plans and operations.

Local development planning

This component actually gathers major initiatives decided after diagnosis and vision setting steps to pursue local development, although not yet framed in a formal village development plan: (1) *Collectively agreed decision to protect the remaining population of baobab trees in the village*: All baobab individuals have been marked and their use prohibited; the use of baobab leaves as animal feed has now shifted to other vegetation resources, crops residues and cereals by-products. This protection initiative is yielding results as women now have baobab fruits available for their processing and income-generating activities. (2) *Establishment of protected areas:* This initiative also results from the initial diagnosis exercise that identified progressive degradation of the vegetation as a major contributory cause to climatic risks (strong wings, erosion, flooding and drought). The community therefore implemented participatory management of two pieces of community land (128 and 240 ha, respectively),

prohibiting fire and wood cutting while allowing grazing. In Daga-Birame, the protected area is actually a band of vegetation surrounding part of the village and, well managed, could serve as windbreak. Overseeing enforcement of the management rules for the above initiatives led to creation of some local institutions (see next section). (3) *Establishment of a borehole*, with the assistance of partner organization, to improve water availability especially during dry season because of the need to irrigate the market gardening productions and the demonstration field on improved tree cultivars. (4) *Access to advisories and technical services*, in contrary to previous situation where no such service was available. This guides farmers in their major livelihoods activities and ensure that constraints for production are tackled.

Strengthening local institutions and knowledge sharing

During the diagnosis step, weak institutional organization and functioning was also pointed out as one of the constraints to undertaking development initiatives. Under the CSV approach, a number of actions have been taken to tackle the issue, among which an innovation platform (IP) has been put in place as a driving force of the CSV development. The IP is regarded as the local institution that decides and leads the implementation of the work plan as defined collectively by the community. It is a functional structure made of all social components of the community, i.e., men, women, youths, traditional and religious leaders and marginalized groups. It also brings together external actors such as technicians, administrative staff, local elected officials, researchers and members of associations, local organizations and savings and loans schemes. The IP bureau is made of 17 members including 6 women, who meet regularly to discuss and suggest decisions to the community for the CSV's activity planning. Major decisions are taken through its general assembly which is held annually, its board meeting every 3 months and neighborhood-level meetings when specific needs arise. Also, information generated (lessons learnt) from implementation of the practices/technologies is shared through the IP. It has allowed women to get land for market gardening and to plant priority local fruit trees in a demonstration plot. The innovation platform also coordinated the process to obtaining agreement from the local authority to protect and manage the community lands. As part of the IP, 3 subcommittees were created and tasked with specific goals: (1) the economic interest group in charge of promoting all income-generating activities; (2) the committee for promoting NTFPs (baobab tree and fruit); and (3) the committee for protected areas in charge of overseeing enforcement of the sustainable management rules.

Added values of the current approach: assessment by local stakeholders and lessons learnt

Stakeholders' perception of key determinants of CSA technologies adoption

The survey targeted stakeholders who involved in the project. Farmers' involvement in the project was materialized by participation to at least three activities. For technicians, besides their participation to activities, they were also in charge of implementing and monitoring specific project activities. The survey revealed that interfarmers exchange visit was selected by 25% of the farmers as the most significant driver for adoption of CSA technologies (Table 4). This visit was based on knowledge sharing on practices and strategies developed by other farmers to cope with their environmental constraints. According to farmers in Ngouye and Daga-Birame, the visit raised collective awareness on the requirement to undertake climate adaptation actions and strategies.

Fruit tree domestication was also considered by 25% of the farmers as the most significant activity that could stimulate technologies adoption. In fact the actual aspect of this activity that was of interest to them was the learning of tree grafting (especially that it was possible to graft baobab tree), tree management, knowledge on use of fruit trees. This activity allows diversification of the formerly existing fruit tree varieties in the village. They also learned how to manage domestication field. The activity is very useful in that it provides nutritive products which are very helpful for population survival. The rest of the farmers had their interests shared between agroforestry trials (10%), forest fruits processing (10%), platform meetings (10%), gardening (5%), climate information sharing (5%), forest surveillance (5%) and sensitization (5%). Technicians had divergent perceptions on the most important intervention/initiative that drives farmers' interest in climate-smart practices adoption; they valued the most the activities on fruit processing,

Table 4 Key determinants of CSA technologies adoption according to stakeholders in the Ngouye–Daga-Birame CSV in Kaffrine Region, Senegal

Activities	Percentage (%)
Interfarmers exchange visit	25
Fruit tree domestication	25
Agroforestry trial	10
Forest fruits processing	10
Platform meetings	10
Gardening	5
Climate information sharing	5
Forest surveillance	5
Sensitization	5

Number of farmers = 20

agroforestry trials, exchange visits, platform meetings and sensitization.

Current CSV versus top-down approaches

Majority of the surveyed farmers (83%) pointed as main difference between the approach used by CCAFS as compared to the top-down in other projects, the aspect of participation to decision making and activities development. For them, it is the local institutions, notably the innovation platform established, that gives this opportunity of synergies between the community, local elected authorities, technicians and the project team. This was really a new thing for them. The effective involvement of women, the demonstration trials, the exchange visits, experience and knowledge sharing with farmers from other areas and the permanent assistance they got from technicians (through the innovation platform) to implement their activities were also mentioned. According to them, in this approach, there is no activity targeting exclusively men and other targeting women; all people gather in the platform meetings to discuss and find solutions to the problems. This view of the farmers is also supported by the technicians who find the CCAFS approach unique in the way they work with local communities. Implemented activities come from discussion with the farmers who are at the center of the debates and have opportunities to raise development problems. These local people feel involved and implement activities by themselves therefore own quickly the process compared to other approaches where field assistants are sent to implement activities planned in a top-down manner by the project team. This project focuses on sensitization of farmers to create awareness, therefore contributing to change in behavior. Only 17% of the farmers think that there is no difference between the CCAFS project and other top-down approach projects implemented in the area as they all have the common objective of pursuing local development.

Conclusion

The initiative to develop the CSV model appeared suitable for the acceptability of climate-smart practices for local development. This approach is based on real involvement of local actors and their partners in the decision-making process of planning, monitoring and evaluation of adaptation capacities to climate change. It is flexible and enables actors to innovate in terms of developing climate-smart practices as well as monitoring, evaluating and improving them. The model fosters overall the development of context-specific land management practices taking into consideration the environmental (sustainable resource management, ecosystem resilience) and socioeconomic (institutional organization, empowerment, food security) challenges. The approach was evaluated by local communities as, by far, efficient compared to previous top-down approaches. The lessons learnt in the current study can be capitalized to replicate the model in sites with similar climatic and socioeconomic conditions. Through the approach there was more enthusiasm and engagement from the farmers to seek for solutions to issues and constraints that they had identified. In light of the results presented, the current top-down approach of the rural support services needs revision. This will require building the capacity of rural technical staffs for using the news tools, understanding and supporting the new approach, as well as, some financial means to support the changes. It should however be noted that some difficulties were encountered in rolling out this approach and need to be beard in mind for successful implementation in other sites. Indeed, the participatory nature of the approach should not be understood as farmers left alone to decide since, quite often, they do not have enough information—are not well aware of all available options—to make sound judgment and decisions; so guidance by researchers and other partners will still be required.

Abbreviations

ACEP: Credit and Savings Alliance for Production; ACIAR: Australian Centre for International Agriculture Research; ANACIM: National Civil Aviation and Meteorological Agency; ANCAR: Agency for Rural and Agricultural Council; BAME: Macro-Economic Analysis Office; CAR: Rural Agricultural Council; CC: climate change; CCAFS: Climate Change, Agriculture and Food Security; CGIAR: Consultative Group on International Agriculture Research; CIAT: International Center for Tropical Agriculture; CMS: Senegal Mutuel Loan; CNCAS: National Agriculture Loan Bank of Senegal; CNRF: National Centre of Forestry Research; CORAF-WECARD: Conseil Ouest et Centre Africain pour la Recherche et le Développement Agricole/West and Central African Council for Agricultural Development; CR: rural commune; CRiSTAL: Community-based Risk Screening Tool—Adaptation and Livelihoods; CSA: climate-smart agriculture; CSV: climate-smart village; DANIDA: Danish International Development Agency; DPV: Direction of Plant Protection; ENSA: National High School of Agriculture; EU: European Union; FMNR: Farmer-Managed Natural Regeneration; ICRAF: World Agroforestry Centre; IFAD: International Fund for Agricultural Development; IICT: Instituto de Investigação Científica Tropical; IP: innovation platform; ISRA: Senegalese Institute of Agricultural Research; LAFE: Agroforestry and Ecological Laboratory; LNRPV: National Research Laboratory on Vegetables Productions; M: men; NTFPs: Non-Timber Forest Products; PAFA: Program Supporting Agricultural Sectors; PAMECAS: Partnership for the Mobilization of Saving and Loan in Senegal; PCD: Participatory Communication for Development; SDC: Swiss Agency for Development and Cooperation; SDDR: County Rural Development Service; TOP-SECACC: Toolkit for Planning and Monitoring and Evaluation of Adaptive Capacities for Climate Change; UFR ST: Science and Technology Training and Research Unit; VAP: Vision-Action-Partnership; W: women; WV: World Vision.

Authors' contributions

DS, BYN, MS, KT, MD and BAC selected the data collection instruments, gathered the data, did data analysis and write up. ON and DT helped in data collection. All authors read and approved the final manuscript.

Author details

[1] Centre National de Recherches Forestières (CNRF/ISRA), BP 2312, Dakar, Senegal. [2] Laboratoire National de Recherches sur les Productions Végétales (LNRPV/ISRA), BP 3120, Dakar, Senegal. [3] Bureau d'analyses macro-économiques (BAME/ISRA), BP 3120, Dakar, Senegal. [4] Ecole Nationale

Supérieure d'Agriculture (ENSA), Université de Thiès, BP A296, Thiès, Senegal. [5] Laboratoire d'Agroforesterie et d'Écologie (LAFE) - Département d'Agroforesterie - UFR ST, Université Assane SECK de Ziguinchor, BP 523, Ziguinchor, Senegal. [6] Agence Nationale de l'Aviation Civile et de la Météorologie (ANACIM), BP 8184, Dakar, Senegal. [7] Agrecol Afrique, BP 347, Thiès, Senegal.

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Competing interests
The authors declare that they have no competing interests.

Availability of supporting data
The datasets analyzed during the current study are available from the corresponding author on request.

Ethical approval and consent to participate
The present study was validated as part of research programs by the scientific committee of Institut Sénégalais de Recherches Agricoles (ISRA), institution to which belongs the first author of this manuscript. Generating scientific knowledge, technological innovations and decision support tools for improving agricultural sector in Senegal is part of the mandate and missions of ISRA (http://www.isra.sn/index.php/presentation-disra-136/mission). Such research involves collecting perceptions of local stakeholders to help direct approaches. All procedures followed in this study were in accordance with the Helsinki Declaration of 1975, as revised in 2000. During the study and before starting each interview, all interviewees were informed about the context of the study and the anonymous nature of the survey. They have all given their consent and have openly and freely answered all questions asked.

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References

1. Oxfam. Annual report oxfam. www.oxfam.org. 2009.
2. Dinar A, Hassan R, Mendelsohn R, Benhin J. Climate change and agriculture in Africa: impact assessment and adaptation strategies. London: EarthScan; 2008.
3. IIED. Réussir la Décentralisation. Institut International pour l'Environnement et le Développement. 2009:13 p.
4. Buldgen A, Piraux M, Dieng A, Schmit G, Compere R. Les élevages de porcs traditionnels du Bassin Arachidier sénégalais. Rev Mond Zootech. 1994;81:63–76.
5. MES. Plan National pour l'Adaptation au changement climatique (PANA) du Sénégal. Ministère de l'environnement du Sénégal. 2006:86 p.
6. Somda J, Sawadogo I, Savadogo M, Zougmoré R, Bationo BA, Moussa AS et al. Analyse participative de la vulnérabilité et planification de l'adaptation au changement climatique dans le Yatenga, Burkina Faso. Programme de recherche du CGIAR sur le Changement Climatique, l'Agriculture et la Sécurité Alimentaire. www.ccafscgiar.org. 2014.
7. Bayala J, Zougmoré R, Ky-Dembele C, Bationo BA, Buah S, Sanogo D, Somda J et al. Towards developing scalable climate-smart village models: approach and lessons learnt from pilot research in West Africa. ICRAF Occasional Paper no. 25. Nairobi: World Agroforestry Centre. 2016.
8. Sanogo D. La communication participative pour le développement (CPD): un outil de valorisation des résultats de la recherche forestière et agroforestière au Sénégal. Science et technique, Lettres, Sciences et humaines. 2014;N°1:21–33.
9. Bessette G. Communication et participation communautaire, Guide pratique de communication participative pour le développement. Presses de l'Université Laval Québec, Canada. 2004:131 p.
10. Swaans K, Pali P. Directives pour les Plateformes d'Innovation: la Facilitation, le Suivi et Évaluation. ILRI Manuel 8 Nairobi, Kenya. 2013:40 p.
11. Giani S, Sanogo R. Medecines traditionnelles et développement local: éthodologies et approches. Universitas Forum. 2011;2(2):1–21.
12. Goudou D, Gué/Traoré J, Ouédraogo M, Segda Z, Badiane Ndour NY, Sall M et al. Village Baseline Study—Site Analysis Report for Kaffrine–Kaffrine, Senegal (SE0112). CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Copenhagen, Denmark. www.ccafscgiar.org. 2012.
13. Förch W, Sijmons K, Mutie I, Kiplimo J, Cramer L, Kristjanson P, Thornton P et al. Core Sites in the CCAFS Regions: East Africa, West Africa and South Asia, Version 3. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. www.ccafs.cgiar.org. 2013.
14. Sarr O, Ngom D, Ngaryo FT, Diatta S, Akpo LE. Etat de la végétation ligneuse dans trois unités d'utilisation des terres d'une zone agropastorale au Sénégal (région de Kaffrine). Int J Biol Chem Sci. 2014;8(6):2669–84.
15. ANSD. Situation Economique et Sociale de la région de Kaffrine en 2013. Avril 2015.
16. Bakhoum C. Diversité et capacités de régénération naturelle du peuplement ligneux dans les systèmes agraires du Bassin Arachidier en zone soudano-sahélienne (région de Kaffrine, Sénégal). Thèse de doctorat en Biologie: Physiologie et productions végétales, UCAD/FST; 2012. p. 154.
17. Ba M, Touré A, Reenberg A. Mapping land use dynamics in Senegal. Case studies from Kaffrine Departments SEREIN Working Paper no. 45, 33 pp. 2004.
18. Somda J, Faye A, N'Djafa Ouaga H. Trousse à outils de planification et suivi-évaluation des capacités d'adaptation au changement climatique. Manuel et Guide d'utilisation Centre Régional AGRHYMET: Niamey, Niger; 2011. p. 88.
19. Ouédraogo M, Dembélé Y, Somé L. Perceptions et stratégies d'adaptation aux changements des précipitations: Cas des paysans du Burkina Faso. Sécheresse. 2010;21(2):87–96.
20. Ouédraogo M, Zougmoré R, Moussa AS, et al. Markets and climate are driving rapid change in farming practices in Savannah West Africa. Reg Environ Change. 2016. doi:10.1007/s10113-016-1029-9.