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RESEARCH ARTICLE

Innovative agricultural extension value chain-based models for smallholder African farmers

Bidjokazo FOFANA (✉)[1], Leonides HALOS-KIM[1], Mercy AKEREDOLU[1], Ande OKIROR[1], Kebba SIMA[1], Deola NAIBAKELAO[1], Mel OLUOCH[1], Fumiko ISEKI[2]

1 Sasakawa Africa Association, Gurd Sholla, Daminarof Building, Addis Ababa 1000, Ethiopia
2 Sasakawa Africa Association, Sasakawa Peace Foundation Building, Tokyo 105-0001, Japan

Abstract The value chain extension strategy of Sasakawa Africa Association focuses on improving the capacity of national agricultural extension systems and follows various thematic areas along the value chain to address key challenges accountable for low income households and poverty in Africa. Farmer learning platform is a model designed to increase crop productivity and encompasses demonstration plots where technological packages demonstrated significantly outperformed other technology plots in crop productivity and average profit margins. Enterprise-oriented production, postharvest and trading centers are value adding models designed to improve the effectiveness of extension and adoption of postharvest and agricultural processing technologies by producers. The use of the above along with necessary capacity building has facilitated the development of profitable business linkages of smallholder farmers with financial institutions and reliable market opportunities. The community association trader-trainer model is a market-oriented business approach applied in combination with other extension models. In 2018, 297 community-based commodity association trader-trainers were mobilized and capacitated to improve farmer group dynamics and developed collective input and output access and cluster aggregation centers at community level where various agricultural produces were mobilized and collectively aggregated, and valued at about 3.9 million USD. The supervised enterprise project model is an innovative agricultural extension model developed along with above models for capacity development of extension agents and transfer of technologies to smallholder farmers. Over 6000 supervised enterprise projects have been introduced into 27 universities in 12 African countries for training front-line extension officers and extension delivery to farming communities.

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Correspondence: bfofana@saa-safe.org

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1 Introduction

The economies of most African countries are largely dependent on smallholder agriculture whose productivity is not increasing and the agricultural sector is facing rapid changes and unprecedented challenges. Extension is an essential pillar in effectively addressing the latter to develop and take required knowledge and solution-based production technologies to smallholder farmers. Thus, the crucial role of agricultural extension services in promoting agricultural innovation cannot be overemphasized. For instance, extension has an important role in bringing about the ‘green revolution’ through the strategic introduction of high-yielding wheat and rice cultivars and the use of farm inputs as recommended by researchers.

Agricultural extension effort has been put more into increasing crop production and productivity with less or no focus on value adding postharvest and agricultural processing technologies along with appropriate marketing strategies[1,2]. As a result, input supply and output marketing systems have not been well developed with limited active contributions of private input and output dealers to market-oriented extension service provision toward meeting the diverse needs of smallholder farmers in the very rapid changing agricultural sector. The poor value chain-based extension service provision is exacerbated by the high extension staff-to-farmer ratio in developing countries which ranges from 1:1800 to 1:3000. The latter has seriously affected the extension effectiveness in many African countries[2].

Many African countries are placing strong emphasis on the commercialization of the smallholder production system, and agricultural production is increasingly becoming market oriented[3]. The value chain approach is proposed as an immediate solution to effectively promote market-oriented agriculture while increasing smallholder farmer income. It describes the full range of activities which are required to bring a product or service from conception, through the different phases of production and delivery to final consumers and final disposal after use[4].

The focus of the extension and technology intervention strategy of Sasakawa Africa Association has therefore been put on value chain-based extension capacity development of national agricultural extension systems in 15 African countries. It consists of designing and disseminating innovative extension models that cut across the entire value chain. Sasakawa Africa Association operations follow thematic areas of crop productivity enhancement, postharvest handling and agricultural processing, and human resource development to address key challenges accountable for low income households and poverty in Africa. The latter include among others low crop productivity[5,6], poor quality produce, high postharvest losses, poor nutrition, weak agricultural extension systems and linkage with research, and poor commercial farmer linkage to input and output markets along the value chain. These challenges have been addressed through innovative extension models that are delivered through on- and off-farm demonstrations, field days, exchange visits, and training on improved pre- and post-harvest agricultural technologies to equip extension agents and smallholder farmers with knowledge and the tools needed.

This paper describes the value chain-based technology intervention and extension approach of Sasakawa Africa Association in Africa and throws light on the synergetic effect of an integrated implementation of extension models on increasing crop productivity and income of smallholder farmers while enhancing extension effectiveness in Africa. Particular attention is given to using solution- and value chain-based extension models for extension knowledge development and sharing including farmer learning platforms, commodity association trader-trainers, production, postharvest and trading centers and supervised enterprise projects. Extension models are implemented in a win-win integrated manner toward ensuring productivity increase (farmer learning platforms), adding value to the generated production surpluses and linking to financial institutions and markets (postharvest and trading centers), improving extension effectiveness (supervised enterprise projects) toward increasing food security and the income of smallholder farmers (commodity association trader-trainers) in Africa.

2 Materials and methods

2.1 Participatory needs assessment

The planning and implementation process of the value chain starts with participatory need assessment done in close collaboration with all active value chain stakeholders including other Sasakawa Africa Association partner extension and research service providers, farming communities, input and output dealers, financial institutions, partner universities and agricultural colleges. The main objective of participatory needs assessment is to identify the genuine needs of smallholder farmers (such as factors constraining increasing crop production and productivity, enterprise selection, capacity building needs for the extension agents, and smallholder farmers and supervised enterprise project students) toward sourcing out need-based pre- and post-harvest technological packages and defining appropriate training topics for relevant value chain stakeholders. It specifically aims at taking right technologies and knowledge to the right sites and for the right target groups. The selection of appropriate baskets of technological options, intervention zones, formal and informal topics and volunteer technology demonstration farmers is done during consultation meetings at community level with partner extension agent representatives of farmer-based organizations and rural opinion leaders. Sasakawa Africa Association and its partner extension agents in collaboration with smallholder farmers, and partner universities and agricultural colleges identify participatory needs assessment-based technological packages and training topics which, when effectively implemented and adopted, may increase efficiency and effectiveness in extension service delivery in Africa.

2.2 Model-based approach in developing the extension platform for technology, dissemination, training and knowledge development strategies

2.2.1 Farmer learning platforms

Farmer learning platforms are instrumental to Sasakawa Africa Association technology intervention strategy toward increasing crop productivity and extension effectiveness. They are particularly designed to investigate the efficiency and effectiveness of technological packages being taken to smallholder farmers by Sasakawa Africa Association in its extension service delivery strategy. Farmer learning platforms encompass four different plot types, comprising community demonstration plots that showcase Sasakawa Africa Association productivity-increasing and climate smart technology, technology adoption plots run by early adopters, model adoption plots are exemplary and commercial technology adoption plots identified through strict selection criteria such as full adoption of the demonstrated technological package run by non-participating farmers. The specifics pertaining to technological packages applied to various demonstration plots are described in Table S1. Climate smart technology is also demonstrated in vulnerable communities operating in fragile agro ecological zones exposed to harsh climate change manifestation. A community demonstration plot illustrates an integrated technological package (with one or many factors) to solve a given problem arising from participatory community consultation and need assessment. The treatment configuration is based on the genuine smallholder farmer needs and problems identified. A community demonstration plot is 1000 m^2 and is placed in the middle of, or is surrounded by, various community practices to clearly illustrate the superiority of improved technological packages under demonstration over community practices. A hosting community is assigned a cluster of four community demonstration plots 4000 m^2 in total size which is set up in each target community to address the production constraining factors. The costs of technological packages applied to the community demonstration plots (inputs, seeds and other good agronomic practices) are fully borne by Sasakawa Africa Association.

In 2018, 804 community demonstration plots were run comprising 384 in Ethiopia and 420 in Nigeria. In Nigeria, 342 model adoption plots were selected from 1575 technology adoption plots to evaluate profitability. Unlike community demonstration plots that are fully financed by Sasakawa Africa Association, model adoption plots are essentially financed by the farmers themselves with Sasakawa Africa Association field staff proving technical backstopping only, hence the need to run economics and make evidence-based decision on the extension recommendation for technological packages.

The community demonstration plot farmers are carefully selected based on criteria such as willingness to apply the full set of productivity-increasing integrated technology packages in compliance with good agricultural practices, conduct farmer-to-farmer step-down training, provide access to demonstration plots for training and awareness enhancement activities such as pre-, mid- and end-of-season training sessions, farmer field days, and yield data. The country-specific priority crops were identified through the participatory needs assessment and included barley, maize, sorghum, teff and wheat in Ethiopia, and groundnut, maize and rice in Nigeria.

Yield data were collected on community development projects, technology adoption plots, model adoption plots (Nigeria only) and community practices, and analysis of variance by country was conducted to evaluate grain yield and related economics of the plot types. When a significant treatment effect was found, mean values were compared using least significant difference (LSD) at 5% probability level[7]. In Nigeria, additional economic variables were investigated for model adoption plots, namely production costs, revenue, profit margin and benefit-cost ratio.

2.2.2 Production, postharvest and trading centers

Parallel to the field demonstration activities, postharvest and trading centers are established in each Sasakawa Africa Association focus country to showcase improved technological options and associated benefits. Postharvest and trading centers operate under actual circumstances affecting operational efficiency, management and profitability. The platform also serves as a venue for the training of extension staff and producers in postharvest and agricultural processing while providing more information on utilization potentials and constraints used to fine-tune technologies or develop and adopt technology dissemination strategies. It constitutes an appropriate platform for an effective implementation of the value chain extension approach that encompasses the production, postharvest and business component with active participation of the private sector for strengthening the marketing and business component. Figure 1 illustrates the key components of postharvest and agricultural processing operation that

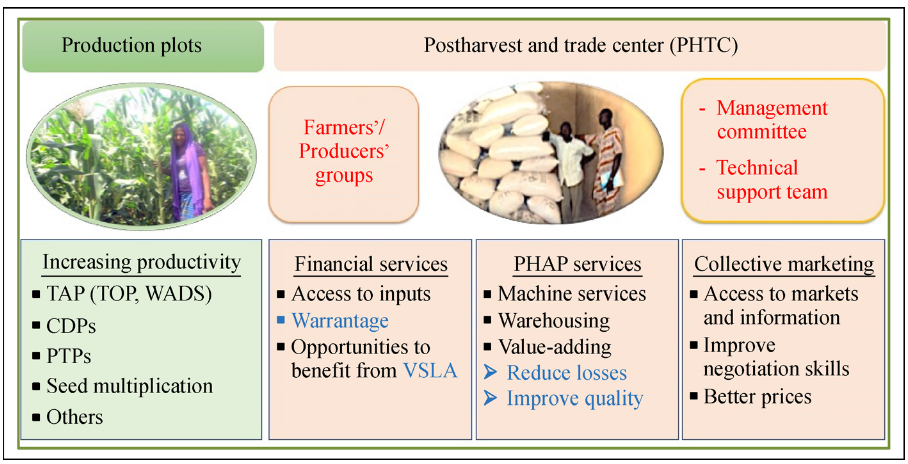

Fig. 1 Sasakawa Africa Association value chain concept encompassing production, postharvest and agricultural processing along with group dynamics toward facilitating smallholder farmer access to input and output markets; technology adoption plot (TAP); technology option plot (TOP); women assisted demonstrations (WADs); community demonstration plots (CDPs); production technology plots (PTPs); village savings and loan association (VSLA); postharvest and trading center (PHTC).

show the Sasakawa Africa Association value chain intervention strategy and show the stepwise interrelated implementation of various activities for value addition and market linkages[8].

The platform in Fig. 1 was established with the active participation of the farmers and agricultural processors at selected sites in the Sasakawa Africa Association countries. The sites are selected based on information from the participatory needs assessment. Some criteria for site selection are crop type and number, cropping patterns, production, crop processing and utilization, market access, and extension service availability. Additionally, the sites were selected for their potential for commercial activities and market expansion. The willingness of producers was also an important selection criterion. Within the crop production and consumption continuum, postharvest and trading centers cover the activities in the post-production sector of the value chain. Post-production consists of various unit operations from harvesting and all subsequent operations conducted until the crop is ready for consumption or sale. Part of the operations in the post-production sector is done in the field (on-farm processing, generally known as primary processing) and includes harvesting, threshing, cleaning/winnowing, drying, storage and decorticating of most major food crops[9].

2.2.3 Commodity association trainer-traders

Commodity association trader-trainers are community-based enterprising farmers or value chain village agents. They are strongly involved in the input and output markets along with the provision of necessary extension services, business support and connections for a sustained viable business at community level. Commodity association trader-trainers mobilize farmer groups and provide the necessary services to improve commercial linkages between producer groups, buyers and other value chain actors (agricultural input companies, insurance, micro finance institutes) (Fig. 2). They are selected based on key selection criteria including (but not limited to) professional skills in working with farmers/groups and subject matter knowledge and experience in safe use, trading and delivery, operating an input shop in the vicinity of target farming communities, knowledge of good agricultural practice, and skills in organizing farmers into commodity specific groups to enhance the pull factor for improved input demand and aggregate marketing.

During production, commodity association trader-trainers provide service to smallholder farmers such as access to improved inputs such as seeds, fertilizers and other agricultural chemicals. Other services such as finance,

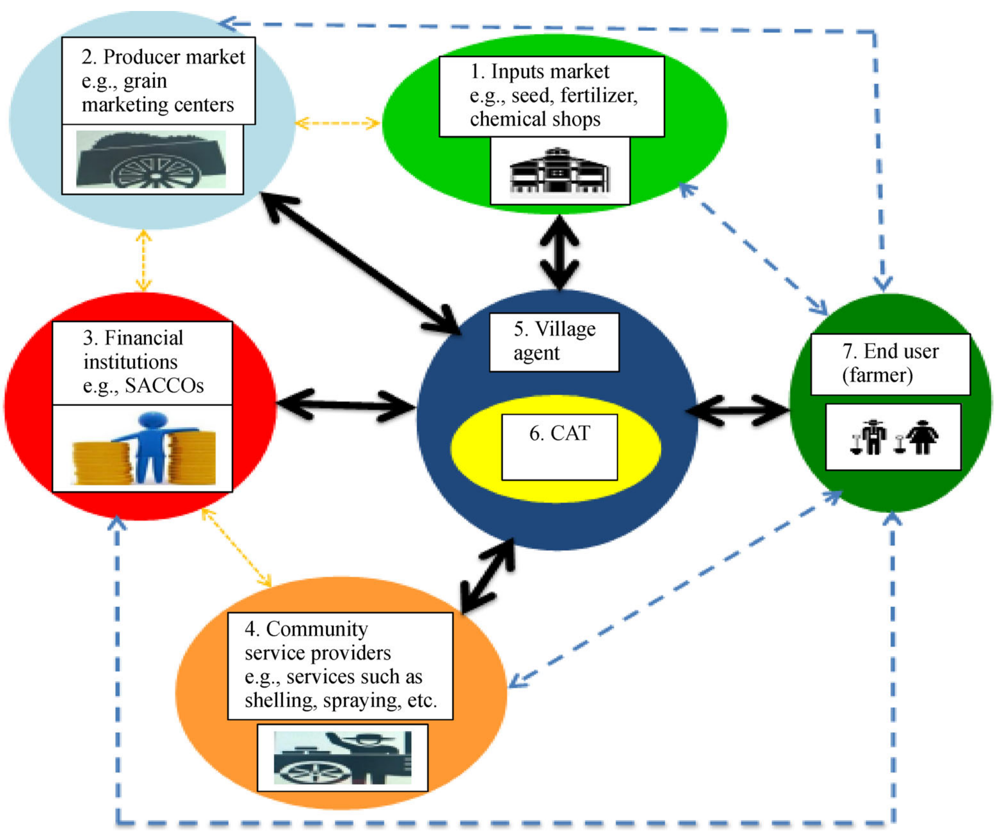

Fig. 2 Sasakawa commodity association trader-trainer business model: commercial linkages among business actors. Commodity association trader and trainer (CAT).

insurance and aggregation services are provided to increase production and value adding postharvest activities. The commodity association trader-trainers then link the farmer to profitable output markets and train on gender to make sure sales from produce are jointly shared by the household leading to joint and improved household planning and increased incomes.

2.2.4 Supervised enterprise projects

The methodology for this work is purely descriptive coupled with secondary data collected from the universities and agricultural colleges currently partnering with Sasakawa Africa Association/Sasakawa Africa Fund for Extension Education and are implementing the supervised enterprise projects model with farmers. The supervised enterprise project model is implemented through the following stages: conduct participatory needs assessment and participatory market analysis, validate participatory needs assessment and participatory market analysis by farmers and other stakeholders, prioritize issues from participatory needs analysis and participatory market analysis, formulate project, secure resources to support project, implement project with end users, supervise project by Sasakawa Africa Association, lecturers, ministry and short message system, evaluate project implemented, and write and present reports. Supervised enterprise projects are an in situ tool for capacity development and technology transfer. The candidates/students develop capacity (knowledge and skills) on the specific technology in question and simultaneously transfer technology to the community. This is underpinned by action research principles and theory but the sequence of activities in supervised enterprise projects is uniquely different from other action research approaches in agriculture. Supervised enterprise projects have learning and development dimensions that include multi-stakeholder platform, extension technology transfer, community development, enterprise development, and learning and sharing.

3 Results and discussion

3.1 Farmer learning platforms

Overall, technological packages demonstrated show significantly different effects on average grain yields of priority crops (Table 1). Community demonstration plots significantly outperformed technology adoption plots and community practices in Ethiopia and Nigeria. In Ethiopia for instance, average grain yields of maize obtained were 5539 $kg \cdot ha^{-1}$ on community demonstration plots, 4858 $kg \cdot ha^{-1}$ on technology adoption plots and 3573 $kg \cdot ha^{-1}$ on community practices. Similar trends were also recorded for wheat, barley sorghum and teff in Ethiopia and rice, maize and groundnut in Nigeria (Table 1). Likewise, in Nigeria, community demonstration plots outperformed both technology adoption plots and community practices and average grain yields of maize recorded were 4823 $kg \cdot ha^{-1}$ on community demonstration plots, 4272 $kg \cdot ha^{-1}$ on technology adoption plots and 2438 $kg \cdot ha^{-1}$ on community practices. Similar trends were also observed for rice and groundnut. The priority crops receiving climate smart technology (Table 1) significantly outperformed community practices. In Nigeria for instance, millet grain yields were 600 $kg \cdot ha^{-1}$ using community practices and 1200 $kg \cdot ha^{-1}$ using climate smart technologies. The respective grain yields of cowpea were 160 and 940 $kg \cdot ha^{-1}$ and of sesame were 193 and 482 $kg \cdot ha^{-1}$. Similarly, climate smart technologies outperformed community practices with millet and sorghum in Mali and maize in Uganda (data not shown).

Overall, technological packages comparing community demonstration plots, technology adoption plots, model adoption plots and community practices in Nigeria showed statistically significant difference in priority crop yield performance (Table 2).

Community demonstration plots significantly outperformed model and technology adoption plots and community practices. Grain yields obtained on model adoption

Table 1 Crop grain yields ($kg \cdot ha^{-1}$) in community demonstration plots (CDPs) as compared with technology adoption plots (TAPs) and community practices (CPs); least significant difference values (LSD) at 5% probability, Ethiopia (n = 384) and Nigeria (n = 420), 2018

Crop	CDPs	TAPs	CPs	Average	LSD (5%)
			Ethiopia		
Maize	5539	4858	3573	4657	355
Wheat	5160	4160	2603	3974	230
Barley	4841	3438	2388	3556	440
Sorghum	4180	3295	2554	3343	393
Teff	2519	2048	1737	2101	64
			Nigeria		
Rice	6148	5505	4269	5307	133
Maize	4823	4272	2438	3844	69
Groundnut	1317	1017	897	1077	45

Table 2 Average grain yields (kg·ha^{-1}) of priority crops in the farmer learning platforms comprising community demonstration plots (CDPs), model adoption plots (MAPs), technology adoption plots (TAPs) and community practices (CPs), Nigeria, 2018

Priority crop	CDPs	MAPs	TAPs	CPs	LSD (5%)
Rice	6148	5786	5505	4269	133
Maize	4823	4984	4272	2438	69
Groundnut	1317	1393	1017	897	45

plots were significantly higher than on technology adoption plots or community plots (Table 1; Table 2). Economic analysis clearly indicates that model adoption plots give clearly higher average profit margins than technology adoption plots or community plots (Table 3). For instance, average maize grain yields recorded were 4984 kg·ha^{-1} on model adoption plots, 4272 kg·ha^{-1} on technology adoption plots and 2438 kg·ha^{-1} on community plots. Corresponding average profit margins were 760 USD on model adoption plots, 517 USD on technology adoption plots and 295 USD on community plots. Similar superiority of model adoption plots over technology adoption plots and community plots was recorded for rice (Table 3). The yield differences recorded between various plot types indicate the superiority of the Sasakawa Africa Association improved technological package over the adoption plots and community practices. The significant yield differences recorded between various demonstration plots can be ascribed to the difference in the efficiency of various technological packages applied to various plots (Table S1) and indicate that improved soil fertility, appropriate fertilizer management and judicious crop variety selection are instrumental to improving crop productivity[6,10–12].

This calls for in-depth investigation to identify the root causes of recorded plot-specific yield and economic performance among technological packages applied. This will contribute to addressing key factors influencing production and knowledge, and hence, bridging recorded gaps in grain yields toward increasing technology adoption in Africa.

Preliminary results obtained using climate smart technologies and practices (such as drought tolerant genetic materials and soil and water conservation measures) clearly indicate significantly higher crop productivity despite the adverse effects of climate change manifestation as compared to the ordinary community demonstration plots.

Consequently, climate smart technologies may effectively contribute to strengthening the resilience of smallholder farming systems as they reduce soil and water erosion while increasing nutrient and water use efficiency. Sasakawa Africa Association will therefore investigate the root causes of observed yield differences in order to identify and address those constraining production and knowledge factors while effectively reducing the yield differences among the applied technological packages. Cognizant of the climate change manifestation and its

Table 3 Average grain yield (kg·ha^{-1}) and economics of priority crops in the farmer learning platforms comprising community demonstration plots (CDPs), model adoption plots (MAPs), technology adoption plots (TAPs) and community practices (CPs), Nigeria, 2018

Variable	CDPs	MAPs	TAPs	CPs
		Rice		
Grain yield/(kg·ha^{-1})	6148	5786	5505	4269
Production costs (USD·ha^{-1})	504	489	459	549
Revenue/(USD·ha^{-1})	2049	1929	1835	1423
Profit/(USD·ha^{-1})	1546	1439	1376	874
Cost benefit ratio	3.07	2.94	2.99	1.59
Internal rate of return/%	206.93	194.11	199.38	59.21
		Maize		
Grain yield/(kg·ha^{-1})	4823	4984	4272	2438
Production costs/(USD·ha^{-1})	514	417	397	281
Revenue/(USD·ha^{-1})	1139	1177	1009	576
Profit/(USD·ha^{-1})	624	760	517	295
Cost benefit ratio	1.21	1.82	1.30	1.05
Internal rate of return/%	21.36	82.09	30.05	4.98

adverse effect on production, value addition technologies and business environment, Sasakawa Africa Association will therefore intensify mainstreaming climate smart technology and taking a value chain approach to climate adaptation and resilience toward building resilience of smallholder farming systems and the business environment.

3.2 Production, postharvest and trading centers

The implementation of postharvest and trading centers in Sasakawa Africa Association focus countries (Ethiopia, Mali, Nigeria and Uganda) from 2012 to 2016 provided important lessons to improve the implementation of the value chain extension approach[13] and includes the production sector and strengthening the marketing aspect. Member farmer organizations were sensitized on the features of the postharvest and trading centers, then the leadership of the postharvest and trading centers were formed, trained in management and guided on developing their business plans. This was followed by training of all members on group dynamics. The use of agricultural machines in the postharvest trading centers necessitates the formation of a technical support group. They are responsible for managing the machines. Additional training was given to the farmer organizations and their constituencies on good agricultural practices along with improved postharvest and agricultural processing technologies and storage management. Farmer organizations are also linked to financial institutions and reliable markets and trained in market negotiations and product promotion. The center is a hub of commercial farming activities of the member farmer organizations. The purpose is to have their produce processed to the quality that the market needs using improved facilities and their developed technical and marketing skills.

Through the postharvest trading centers, the postharvest and agriculture-related service provision has also developed and has proved to be effective in facilitating smallholder farmer access to postharvest equipment which otherwise may have been beyond their reach. Successful cases have been reported whereby equipment was purchased by private individuals and used to provide agricultural processing services to smallholder farmers. For example, the portable grating machine introduced in Nigeria did not have many units sold to processors, but the few units were able to reach more processors. This was attributed to the fact that the service provider was able to go around the villages with the machine and collect fees for grating services rendered. The threshing service provider for teff farmers is also working well in Ethiopia. Over 300 threshers are already reportedly purchased by farmers and private entrepreneurs over five years. The threshers are being used for processing their own crops and providing threshing services to teff farmers in their community[14].

The Sasakawa Africa Association service provision strategy is meant to smooth and/or accelerate the adoption and scaling-up process of improved postharvest handling, storage and agricultural processing technologies in its focus countries. Furthermore, Sasakawa Africa Association has identified enterprising and motivated producers and trained them in agricultural processing enterprise management and operational and maintenance requirements of the recommended postharvest technology. Business linkages have been facilitated to agricultural machinery manufacturers, spare parts dealers and small machine shops for effective assistance in the repair and maintenance of the postharvest and agricultural processing machines. In some instances, individual producers or groups who envisage to venture into service provision but lack capital to buy the machinery, are linked to finance institutions for proper assistance in accessing credits. The success of the postharvest intervention strategy will chiefly depend on the efficiency and effectiveness of the relevant technologies and associated market opportunities. Successful private service provision in combination with necessary capacity-building in and sensitization about postharvest and trading center technology along with profitable commercial linkages will be instrumental in sustaining the postharvest and trading centers in the Sasakawa Africa Association focus countries.

3.3 Commodity association trader-trainers

In 2018, Sasakawa Africa Association was able to mobilize and capacitate 297 community-based commodity association trader-trainers across its focus countries comprising Ethiopia, Mali, Nigeria and Uganda. The capacitated commodity association trader-trainers were able to mobilize farmers in groups of 15 to 20 members at community level totaling 70845 across the Sasakawa Africa Association focus countries. They organized and consolidated farmer group dynamics while developing collective input access and marketing at community level. After mobilizing farmers, they were able to build commodity associations at appropriate collection centers for planning and implementing product specific clusters and collection centers toward ensuring access to and usage of quality inputs and produce aggregation centers for collective marketing. Commodity association trader-trainers were able to support farmers in mobilizing 21.7 kt, valued at about 3.9 million USD. In doing so, commodity association trader-trainers did not only enhance cluster competitiveness but also created an enabling environment to effectively implement the value chain approach toward increasing smallholder farmer incomes, job creation and livelihoods at community level.

According to the feedback from the commodity association trader-trainers, human capital development is the most important business component that was ranked maximum, especially knowledge development of commodity association trader-trainers in business skills, considered instrumental in identifying and finding solutions for farmer needs. Aggregation centers have provided a value chain-forum for farmers to market their produce, purchase improved agricultural inputs, access market information, and access linkages with other value chain actors such as suppliers and produce buyers, financial institutions and access to postharvest services. The centers have also been platforms for farmer mobilization and training, critical to the sustainability of the commodity association trader-trainer model in the agricultural business development process. The second ranked component were the linkages with other networks and partnerships for provision of agricultural inputs and access to markets and other pre- and post-harvest technology related supportive equipment. Sasakawa Africa Association not only links commodity association trader-trainers with smallholder farmers but also facilitates market linkages, resulting in rural job creation among youth, people with special needs and women.

3.4 Supervised enterprise projects

Many universities and agricultural colleges have adopted and implemented the supervised enterprise project models in Africa[15]. A total of 5784 projects were implemented in close collaboration with farmers by students from Sasakawa Africa Association/Sasakawa Africa Fund for Extension Education partner universities and agricultural colleges in various countries since the inception of the program (Table S2). About 1526 projects are still being implemented, totaling 7310 projects. In terms of distribution of the supervised enterprise projects, countries such as Ethiopia and Nigeria have the highest because there are many partner universities of Sasakawa Africa Association/Sasakawa Africa Fund for Extension Education that are implementing supervised enterprise projects in the country. Also, the high number of supervised enterprise projects implemented in Ghana, Mali, Tanzania is explained by their many years of involvement in mid-career training and the number of institutions in the country which require that students implement the supervised enterprise projects as part of the curriculum.

This high acceptance of the supervised enterprise model by universities and agricultural colleges has helped involve farmer groups and communities in the conceptualization and realization of various projects along commodity value chains. The increasing number of supervised enterprise project candidates along with growing interest of universities in supervised enterprise projects is likely to contribute to the lowering of staff-to-farmer ratios in Sasakawa Africa Association focus countries while increasing the extension effectiveness in these countries. This is in line with studies indicating that the supervised enterprise projects, which enable students to work with relevant stakeholders to identify and tackle agricultural problems in farming communities through experiential extension approaches and action research, are an essential part of agricultural curricula toward adapting and improving the formal extension education training in universities and agricultural colleges[16]. Other studies concluded that supervised enterprise projects are a unique and important component of the Sasakawa Africa Fund for Extension Education training program[7]. Supervised enterprise projects are supported by experiential learning theory in which skills such as learning in real-life contexts, problem solving, learning by doing, and learning through projects, are expected to be acquired and mastered by trainees. Sasakawa Africa Fund for Extension Education enhances the process of continuing education to extension officers in Africa[17]. The supervised enterprise project model enhances community-based learning, benefiting student skill learning and farmers' extension needs[18]. All the graduates had attained competencies that were rated from high to very high, and improvement in academic status, knowledge and skills in human relations as well as technical areas in agriculture, and attitude to work, were perceived as the major benefits of the extension program[19]. Sasakawa Africa Fund for Extension Education trained agents had more competence in the dissemination of selected climate smart technology innovations[20]. The high competence score was attributed to the supervised enterprise project experience in practicing the innovation before dissemination. The implication is that extension curriculum should incorporate the aspect of learning by doing in order to improve the extension effectiveness through need-based dissemination of agricultural innovations.

4 Conclusions

The value chain extension approach implemented by the Sasakawa Africa Association has proven to effectively contribute to increasing crop productivity and income of smallholder farmers while facilitating their timely access to required finance, inputs and output markets along with the use of appropriate preharvest and value-adding postharvest technological packages. Nevertheless, recent climate-related natural hazards are likely to compromise the recorded crop productivity increase. Also, the value chain was participatory piloted at a small scale with limited numbers of participating smallholder farmers.

Increasing the scale will undoubtedly necessitate factoring the adverse effects of climate change and benefits of digital technology into the Sasakawa Africa Association value chain intervention strategy. In doing so, the Sasakawa Africa Association approach is likely to sustainably improve resilience and adaptation of smallholder farmers to climate change and benefit thousands of them.

Supplementary materials The online version of this article at https://doi.org/10.15302/J-FASE-2020358 contains supplementary materials (Tables S1–S2).

Compliance with ethics guidelines Bidjokazo Fofana, Leonides Halos-Kim, Mercy Akeredolu, Ande Okiror, Kebba Sima, Deola Naibakelao, Mel Oluoch, and Fumiko Iseki declare that they have no conflicts of interest or financial conflicts to disclose.

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