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Relative importance of functions of innovation system on cassava climate smart farming in Kenya

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Functions of innovation systems framework have established their value as tools for exploring socio-technological transitions and economic development. Although the "seven functions" model has demonstrated its academic value across a vast literature, there have been few attempts to explore the role of the model in climate smart farming. Therefore, the aim of this study is to determine relative importance of functions of innovation system on cassava climate smart farming in Kenya. The study focused on the following seven functions of innovations; entrepreneurial activities, knowledge development and diffusion, search for guidance, market development and stabilization, resource mobilization and legitimacy development. Data were collected from 150 cassva farmers in Nyando Sub-County, Kenya. Data analysis deployed the Best-Worst scaling (BWS) choice method and expanded to include the multinomial logistic regression modelling. Results revealed that knowledge development, diffusion and resource mobilization were the functions of innovation systems ranked highest in terms of shared importance among the seven innovation functions. In fostering cassava innovations, their relative importance was knowledge development (19.17%), knowledge diffusion (18.86%) and resource mobilization (14.88%). Evidence from the multinomial logistic regression revealed that farmers chose knowledge development as most important innovation function to foster cassava innovations in the Nyando CSV.

Key words: Entrepreneurial activity, knowledge development, market formation, resource mobilization.

INTRODUCTION

Understanding the emergence of innovation systems and their role has been central to monitoring and evaluating technological innovation change processes in most organizations (Markard et al., 2015). In essence, the key activities that contribute to the development of the innovation system, as well as the functions of the innovation systems, have received a lot of attention (Nevzorova and Karakaya, 2020). It is already evident

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that climate is rapidly changing and is projected to further continue changing, but the extent may be slowed with concerted and collective adaptation and mitigation actions (Okonya et al., 2013). This necessitates scaling technologies and innovations that contribute to effective adaptation and mitigation of the changing climate, and this necessity has led to the evolution of climate smart agriculture (CSA). The Food and Agriculture Organization (2013), defines CSA with three main pillars: increasing agricultural productivity and sustainable incomes (food security), adapting to, and building resilience to climate change (adaptation), and reducing and/or eliminating greenhouse gas emissions (mitigation). Realizing the triple co-benefits of CSA application, as defined, requires an integrated approach that is responsive to specific local conditions and requires coordinated action across agricultural sectors.

Scaling of CSA practices have been fostered through Climate Smart Village (CSV), which is an innovation platform that facilitates multi-stakeholder collective actions and innovation processes (Kilelu et al., 2017; Klerkz et al., 2010; Sotarauta and Pulkkinen, 2011). In the CSV, beneficiaries learn, experiment together, exchange information, and compare experiences. CVS thus provides an innovation platform in the concept of an agricultural innovation system because of the opportunity to engage with a diverse range of partners, including research, extension, development agents, the private sector, and empowered farmer institutions and organizations. Therefore, CVS aims to close knowledge gaps and promote the scaling of climate smart cassava innovation technology.

However, for the process to be effective, fostering climate smart innovations require additional efforts through reinforcement of the seven innovation functions. In theory, the innovation functions are critical processes that actively contribute to technological development, diffusion, and application. Furthermore, some authors including Planko et al. (2017) and Suurs et al. (2010) acknowledge that entrepreneurs are important in innovation systems because they take risks, turn ideas into business opportunities, and transform innovations. With regards to this study, the seven functions of innovation system that were considered included: knowledge diffusion, entrepreneurship, guidance of the search, knowledge development, market formation, resource mobilization and support from advocacy coalition (Fielke et al., 2018; Markard et al., 2015).

The Nyando CSV is an example of innovation platform that championed adaptation to and mitigation of the climate change. The climate platform incorporated the seven functions in its operations. Knowledge development involved testing and validating cassava technologies within local contexts through farm-level demonstrations and trials. Farm demonstrations were designed to enable farmers learn about the new technology. Knowledge development plays a critical role in helping farmers learn about climate adaptation, cassava production, processing, and building resilience to climate change (Hekkert et al., 2007). These are prerequisites for innovation systems that encourage innovation by improving technological performance. Through knowledge development, diversity for climate change adaptation helps build farmers' capacity to improve cassava yield. Knowledge diffusion is important because it ensures that the new technology is communicated throughout the population to ensure that the adoption of the new technology increases steadily over time (Jiafu et al., 2018).

Entrepreneurship function is important because it helps combine existing resources to introduce new methods and products in the market (Singh and Gaur, 2018). Entrepreneurship involved improving farmers' living standards through creativity and value addition to cassava products. It helped promote orientation in cassava production, processing, and trading and enabled new markets to emerge. The market formation function is important because it identifies groups to target and how to improve the adoption of innovation (Nenonen et al., 2019). In Nyando CSV, market formation involved creating policy for adoption and bringing together national and county government to ensure that policy decisions were consistent with the latest technological insights and that research and development agendas are influenced by changing norms and values.

Resource mobilization links farmers to credit lenders to help address the needs for farm inputs and farm expenses. Access to affordable credits and funding support for cassava production, processing, and trade is critical for success in climate change mitigation and adaptation in Nyando (Konig et al., 2018). Resource mobilization is an important function of innovation because it helps in selection of key areas of interest for further investigation because resources are always limited (Yang et al., 2019). The next function, the guidance of search, increases access to high-demand markets for cassava products. It is important because it shapes the expectations, needs and requirements of the actors in the emerging technology. The last function, support from advocacy coalitions, helps empower farmer groups and service providers in cassava production, processing, and trading (Nevzorova and Kutcherov, 2021). It is a critical function because it spans all levels of government from county to national government.

The changing climate, now with more frequency and severe extremes, disproportionately affect smallholder farmers numbering over 1.5 billion people worldwide, who are heavily dependent on rural agricultural livelihoods activities (World Bank Report, 2021). This means that there is a need to identify approaches that may strengthen their adaptive capacity to improve their ability to mitigate the effects of climate change in their agrienterprises. The activities "that shape the needs, requirements, and expectations of actors with respect to further support the emerging technology" can effectively guide solution search, usually sparking virtuous loops of more sustainable technologies (Suurs et al., 2010). This necessitates intervention by relevant stakeholders to devise methods of changing the ways smallholder farmers respond to the effects and impacts of climate change.

Most stakeholders do not include market participation, which is a barrier to increasing productivity. While cassava demand is on an increasing trend in the Nyando CSV, cassava production, marketing, and processing has remained somewhat stagnant, except for a few outstanding farmers (positive deviants) in cassava production and marketing who have innovative capacity relevant to advancing cassava innovation. Through knowledge exchange and co-innovation, collaborative learning action has been used to initiate improvements in agricultural systems, but application in cassava innovation has rarely been documented in the CSVs, especially in Eastern Africa, where several CSVs were established. The objective of this study was to determine the relative importance of seven functions of innovation systems in fostering cassava innovation in the Nyando CSV.

The success stories of climate smart innovation platforms in Kenya and other regions in Africa and Asia are well documented in the literature. For instance, climate smart innovation has increased adoption rates, agricultural productivity, incomes, gender equality, and food security (Recha et al., 2017). However, the contribution and importance of the seven functions of agricultural systems to the success stories of the innovation platform has not been well captured in the past and present literature. This study filled this gap by evaluating the importance of the seven functions in fostering cassava innovations in Nyando climate smart village.

METHODOLOGY

Study area

The research was conducted in the Nyando Sub-County of Kisumu County in Kenya focusing on the Nyando Climate Smart Villages (CSV). The Nyando Sub-County is located between longitude 33° 20' - 35° 20' East and latitude 0° 20' - 0° 50' South and has a population of approximately 73,227 people (KNBS, 2019). The Nyando Sub-County was purposively chosen for the study as one of the CSVs established in 2011-2012 to test cassava climate smart innovations, among other climate smart agriculture interventions. This is a designated hotspot of changing and variable climate, which has an impact on rural livelihoods. As a result, the Climate Change and Food Security (CCAFS) program established the Nyando CSV in 2011-2012 to pilot several climate-smart interventions tailored to the needs of the local community (Recha et al., 2017).

Data collection method used for this study was a combination of descriptive survey and participatory action research (PAR) research design, with target population of households in Jimo location, which included 11 CSVs with a total population of 10,000 households (KNBS, 2019). The target population was chosen because cassava was one of the climate smart agriculture technologies promoted in that location and tailored to the needs of the local community. However, information on fostered cassava innovations is scanty (Recha et al., 2017). The sampling frame was members of climate-smart village farmer groups which comprised 1500 members. Lists of members were obtained from group leaders and inputted in Excel. Information obtained from group leaders, Kenya Agricultural and Livestock Research organization, and extension officers indicated that 1,500 farmers, current and previous members, used climate-smart innovation. Thus, we followed the recommended sample size of 10% of the population (Mugenda and Mugenda, 2003) and determined a sample size of 150 farmers. Selection of farmers from lists provided by extension officers followed systematic random sampling technique with a k^{th} element fixed at 10 which was obtained by dividing the sample population by the desired sample size.

Data collection

Semi-structured questionnaire was used to collect information pertaining to several variables. The first set was socioeconomic variables that were critical to understanding the study subjects. The socioeconomic variables were sex of the famers, household headship, age of household head, marital status, educational attainment, occupation, household size, household decision-making, total and crop land, and land allocated to cassava production, and membership to climate smart farmer groups. Variables of interest were the seven functions of innovation (Knowledge diffusion, Entrepreneurship, Guidance of the search, Knowledge development, Market formation, Resource mobilization and Support from advocacy coalition), which were measured as likert scale items (most important/effective/facilitative and the least important/effective/facilitative) that required the respondents to identify the most important and the least important function in fostering cassava innovation. There were seven sets that required farmers identifying the most important and least functions. Enumerators were trained on questionnaire administration and interviewing farmers. Pilot study was conducted on a sample of 30 farmers to pre-test the tool in Chemilil District. The results of the pilot were used to refine the tool prior to the data collection process. Face-to-face interviews were used to collect data from farmers. The collected was downloaded, checked for consistencies, and cleaned in readiness for analysis.

Data analysis

Model estimation

A relative importance was computed from Best-Worst scaling (BWS) choice method which assumes that the probability that a farmer chooses a pair in a particular set is proportional to the difference between the ‘Best’ and ‘Worst’ item on the scale of importance (Flynn et al., 2007). Computation of the relative importance of each of the seven functions of innovation system (Markard *et al.,* 2015) was stepwise. The number of times each function was chosen as the most and least important to obtain the total best (most important) and total worst (least important) was counted, followed by the computation of B-W scores by subtracting the total worst from the total best. A positive value indicated that the function was chosen as the most important more times as it was chosen as the least important. The BW scores were then standardized by dividing the B-W difference by the sum frequency counts times three, implying that all choices appeared three times while a combination of each function of innovation systems

Table 1. Socioeconomic characteristics of respondents by type of farmer.

Variable	Variable type	Pooled (N=150)
Sex of farmer (%)	Nominal (0=Female, 1=Male)	
Female		56.67
Male		43.33
Percent of male-headed households	Binary (1=Male HH, 0=Female HH)	69.33
Mean age of household head	Continuous (years)	55.01
Marital status	Binary (1=Married, 0 otherwise)	75.33
Educational attainment (%)	Ordinal (1=No formal education, 2=Primary, 3=Secondary, 4=post-secondary)	
No formal education		18
Primary		49.33
Secondary		29.33
Post-secondary		3.33
Farming as main occupation (%)	Binary (1=Farming, 0=Off-farm employment)	66.67
Household size	Discrete	6.4
Farm decision maker (%)	Binary (1=Head, 0=Spouse)	
Head		92.67
Spouse		7.33
Total land size owned by household	Continuous (Acres)	3.11
Total cropped land	Continuous (Acres)	2.52
Area under improved cassava	Continuous (Acres)	0.5
Member of climate smart village (%)	Nominal (1=Yes, 0=No)	88
Number of years of group membership	Discrete	7.48

Source: Survey data

appeared (Marley and Louviere, 2005).

The relative importance of the functions was then calculated using the square root of (B/W). The square root (B/W) was then multiplied by a factor, with the most important having the highest square root (B/W) set to 100% (Louviere et al., 2015). The relative square root (B/W) ratio of all items was then used for comparison. The relative importance of each of the innovation systems functions was expressed as a percentage, which can be interpreted as the probability of being chosen as the most important (Louviere et al., 2015). The BWS analysis was expanded to include econometric analysis to estimate the likelihoods of farmers selecting the seven functions using the multinomial logit model. The model was used to estimate the probabilities that a farmer chooses the best and worst pairs **t** number of times using the explained expressions in the form of (Hausman and McFadden, 1984):

$$\mathrm{P}(\,bw/\,t\,) = \frac{\exp\left(\,\beta_b - \beta_w\right)}{\sum_{\mathrm{ij}} \exp\left(\,\beta_{\mathrm{i}} - \beta_{\mathrm{j}}\right)}$$

To ease the interpretation of multinomial logit model coefficients, shared importance was used to assess the significance of the seven functions in fostering cassava innovation. According to Lusk and Briggeman (2009), shared importance or preference is the predicted probability that one item from a continuum will be chosen as the most important and is defined in the form of:

$$\text{Share of importance} = S_i = \frac{e^{\hat{\beta}}}{\sum_{m=1} e^{\hat{\beta}_m}}$$

Where $\hat{\beta}_i$ is the predicted probability that function i is selected as most important in fostering cassava innovation. The summation of the shared of importance of the seven functions is one, which shows how important a function is in fostering cassava innovation over other functions on a ratio scale.

RESULTS AND DISCUSSION

Descriptive statistics

The socio-demographics of the sampled farmers are presented in Table 1. The household demographics collected for this study included sex, male-headed households, age, marital status, education level, occupation, household size, farm decision maker, land size, membership to climate smart village and number of years of group membership. In terms of the sex of the respondents 57% were female while male was 47%. Out of the total sample, male-headed households constituted 69% compared to 21% female-headed households. The results are also consistent to the finding on farm decision maker; the head who was a man were the majority (93%) in making decisions related to farming. The farmers were aged between 27 and 89, with an average of 55 years. Thus, suggesting that most were experienced in cassava farming and were aware of the functions of innovation

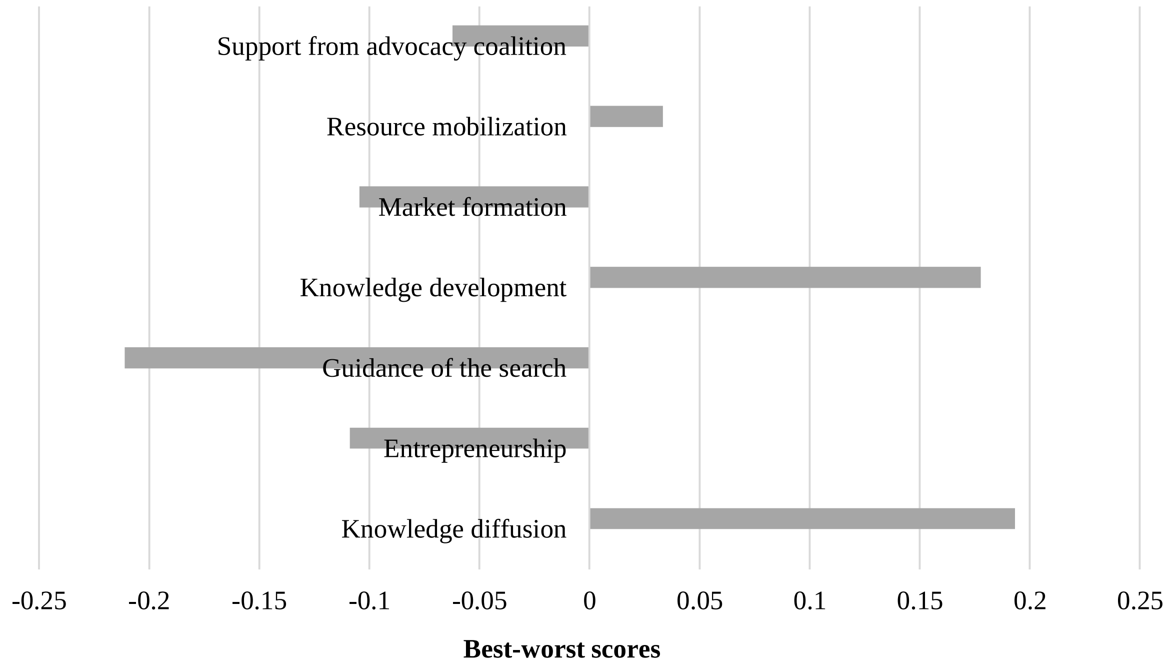

Figure 1. Best-worst scores associated with each of the seven functions of innovation systems supporting fostering cassava innovation.
Source Survey data.

systems. In terms of education level, 18, 49, 29 and 3% had attained no formal education, primary, secondary, and post-secondary levels of education, respectively. In terms of the main occupation for the respondents, 67% depended on farming, while only 33% were dependant of off-farm employment. The mean house size for the respondents was 7 which is above the mean household size in Kenya (4 members) as per the population survey in 2019 (KNBS, 2019). With regards to the land size owned by the farmers, the mean land size was 3.11 acres with 2.52 under crop farming. However, the area under cassava was only 0.5 acres which shows that the land allocated to cassava was very small compared to the total land under other crops. Finally, 88% of the respondents were members of climate smart villages with duration of membership being on average 7.5 years. This indicates that these farmers were well exposed to climate smart farming and innovation platform such as climate smart villages would capacity build them on functions of innovation system.

Relative importance estimates for the seven functions of innovation systems

Figure 1 illustrates the best-worst scores for each of the seven functions of innovation systems supporting cassava innovation in the Nyando CSVs. A positive value indicates that the function was chosen as the most important function more times than it was chosen as the least important function. The illustration reveals that three of the seven functions were chosen as the most important more times as they were chosen as the least important. These were the functions of knowledge development, knowledge diffusion, and resource mobilization. Four of the seven functions were chosen as the least important more often than they were chosen as the most important. These functions included market formation, advocacy coalition support, entrepreneurship, and search guidance.

Table 2 summarizes the relative importance of each of the seven functions of innovation systems that support cassava innovation in the Nyando CSVs. According to the findings, the functions ranked in order of relative importance from most important to least important were knowledge development (19.17%), knowledge diffusion (18.86%), and resource mobilization (14.88%). The other four functions (market formation, advocacy coalition support, entrepreneurship, and search guidance) were ranked between 13 and 11% in importance. However, the estimates revealed a narrow range of relative importance, a range between 11 and 19%. Farmers in Nyando CSVs chose knowledge development and dissemination as two of the most important innovation system functions. Sharing of information and providing platforms where farmers can easily access information is essential. Knowledge development and cassava innovation diffusion can be effectively developed through a

Table 2. The relative importance of each of the seven functions of innovation systems that support fostering cassava innovation.

Functions of innovation systems	B	W	B-W scores	Sqrt (B/W)	Standardized ratio scale	Relative importance (%)	Ranking
Knowledge diffusion	201	114	0.19	1.33	98.36	18.86	2
Entrepreneurship	107	156	-0.11	0.83	61.35	11.76	6
Guidance of the search	109	204	-0.21	0.73	54.15	10.38	7
Knowledge development	178	98	0.18	1.35	100.00	19.17	1
Market formation	126	173	-0.10	0.85	63.22	12.12	5
Resource mobilization	169	154	0.03	1.05	77.60	14.88	3
Support from advocacy coalition	123	151	-0.06	0.90	66.85	12.82	4

Source: Survey data

variety of desktop research, feasibility studies and assessments, reports, and research and development projects. These findings concur with those of Markard et al. (2016), who emphasize the importance of knowledge development as the foundation of any innovation process. Knowledge and dissemination ideologies, which help to inform sound decisions and policies, are at the heart of all innovations.

The benefits of adopting cassava products previously used by the targeted customers justify knowledge development. Customers are critical in providing information such as product attributes, packaging, and value addition processes.
Furthermore, organizing seminars, conferences, and product training workshops encourages information sharing and dissemination to various stakeholders. This also helps to reach a large number of people who are interested in cassava farming, which improves the innovation processes. As a result, it is critical that both technological and non-technological research and development be conducted in order for the cassava innovation system to function.'

According to the respondents, one of the most important innovation functions that aid them in fostering cassava innovation is resource mobilization. For cassava innovation to be sustainable, resource mobilization is important. Training of individuals to be experts in cassava production, processing and marketing is needed to stimulate knowledge transfer to communities. These qualified specialists are viewed as the face of successful cassava innovations. While human factors are required, stakeholders in cassava production must also mobilize financial resources. These findings are consistent with the findings of Hermans et al. (2019), who determined that various investments are required to support innovations, such as capital funding for research and development, placement of subsidies to support project and market concept development, and training of experts in a specific innovation opportunity who can also train others to take up the new opportunity. Pigford et al. (2018), agree, noting that human, financial, and material factors are critical inputs for all innovation system developments worldwide.

Probabilities of farmers selecting the seven functions

Table 3 shows the results of the maximum likelihood multinomial logit model estimates of the probabilities of farmers selecting any of the seven functions as important for fostering cassava innovation. Only one function, knowledge development, was statistically significant in the probabilities of farmers selecting the seven functions to foster cassava innovation in Nyando CSV. Farmers value the opportunity to participate in the development of CSA innovations. Most farmers attributed this to the fact that their needs can be met by listening to their decisions prior to the introduction of a new innovative technology. Furthermore, knowledge development spans across several stakeholders in the cassava innovation platform, from buyers of cassava to farmers who are the producers. This means ideas and insights are generated and implemented throughout the knowledge development process to meet the needs of all stakeholders involved, resulting in its efficiency in fostering cassava innovations. These findings are consistent with Fu et al. (2019), who stated that knowledge development is the foundation of all innovation systems because it is through it that knowledge on required needs and solutions to those needs are brought to the table. This is then translated into sound policies and decisions in order to make

Table 3. Multinomial logit estimates of the best innovation functions for fostering cassava innovation and shared importance.

Function	Mean	SE	Shared importance	
			Mean	SD
Knowledge diffusion	0.140	0.306	0.174	0.129
Entrepreneurship	-0.288	0.342	0.101	0.080
Guidance of the search	-0.288	0.342	0.119	0.109
Knowledge development	0.642*	0.276	0.275	0.131
Market formation	-0.163	0.330	0.092	0.077
Resource mobilization	0.095	0.309	0.128	0.063
Support from advocacy coalitions	Ref.		0.128	0.063

* $p < 0.05$.
Source: Survey data.

the CSA innovations viable and sustainable. Furthermore, knowledge development, knowledge diffusion, and resource mobilization were associated with positive coefficients (0.140, 0.642, 0.095), whereas entrepreneurship (-0.288), search guidance (-0.288), and market formation (-0.163) were associated with negative coefficients. The most important functions of innovation systems in fostering cassava innovation in the Nyando CSV were, in order of importance, knowledge development, knowledge diffusion, and resource mobilization. In comparison to advocacy coalition support, entrepreneurship, search guidance, and market formation ranked low in importance to fostering cassava innovation. A third (28%) of farmers in this study ranked knowledge development as important as knowledge diffusion, while 13% ranked resource mobilization as important as knowledge development in fostering cassava innovations.

Conclusion

The objective of this study was to determine the relative importance of seven functions of innovation systems in fostering cassava innovation. Climate smart innovation functions must be deployed in order to foster climate smart cassava innovations in Nyando CSV. The innovation functions are thus critical not only for sustaining economic development among CSVs, but also for encouraging innovation adoption. To estimate the relative and shared importance of the seven innovation functions in fostering cassava innovations, the Best-Worst Approach Showed that Knowledge development emerged as a strong function in fostering climate smart cassava innovations among farmers. This meant that, while other roles were important, farmers were more interested in learning about a new technological innovation and how it would benefit them. This observation is suggestive of the presence of research institutions being some of the actors in cassava value chain having had influencing role play in the knowledge development. Therefore, while the seven functions are important, policymakers should support knowledge development in a multi-stakeholder platform to foster knowledge acquisition, transfer, and diffusion among farmers to encourage improved climate smart cassava innovations.

To achieve economies of scale with CSA cassava innovations through integration of the innovation functions, the government must collaborate with the private sector, farmers, private traders, and agricultural research centers. Even though entrepreneurial activities were among the least important functions in fostering climate smart cassava innovations, there is a need to encourage entrepreneurial attitudes (innovativeness, proactiveness, and risk taking) among farmers toward the adoption of the innovations. This has significant policy implications, particularly if a new improved cassava variety is to be introduced. Given that entrepreneurial orientations have a variable influence on cassava innovation adoption rates, programs geared toward entrepreneurial training through knowledge development and dissemination to address the three key aspects of proactiveness, innovation, and risk taking among cassava farmers must be implemented.

CONFLICTS OF INTERESTS

The authors have not declared any conflicts of interests.

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