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Gender and access to complex and gender-biased agricultural technology information and knowledge: Evidence from smart-valleys in West Africa

Florent Mahoukede Kinkingninhoun Medagbe[1], Anne Floquet[2], Roch Lambert Mongbo[2], Kossi Nounagnon Augustin Aoudji[2], Gaudiose Mujawamariya[3] and Nestor René Ahoyo Adjovi[4]

Abstract

This paper identifies some ways to effectively transfer complex and gender-biased technology information and knowledge (TIK) to both men and women by analyzing the diffusion of Smart-valleys technology in West-Africa. ANOVA and Fisher's exact tests were applied to data collected from 1120 lowland rice farmers in West Africa. Results confirm the general gender inequality in TIK communication with male farmers having more access to Smart-valleys TIK than female lowland farmers. Only few female communicators were used in Smart-valleys TIK transfer even if they were found to be as efficient as men at communicating and teaching. However, opposite results obtained in Togo in particular reveal that it is possible to ensure gender equality in agricultural TIK communication, even in case of complex and gender-bias technologies, if specific gender mainstreaming and gender equity actions are undertaken during technology diffusion. Women-to-women communication improved female farmers access to Smart-valleys TIK confirming that involving female communicators will reduce gender inequality in TIK diffusion. On-farm demonstration was identified as the most effective approach, not only in Smart-valleys TIK communication, but also in ensuring gender equity in access of both male and female farmers to the TIK. Therefore, on-farm demonstration combined with oral explanations should be adopted as the main approach in complex and gender-biased technologies diffusion in general, and in Smart-valleys diffusion in particular.

Keywords

Gender, Smart-valleys, complex technology, gender-biased technology, access to TIK, extension approach

Introduction

The development, testing and dissemination of new agricultural technologies are the core of increasing productivity, improving incomes and food security, sustainability and resilience of small-scale farming systems (InterAcademy Partnership, 2018; Thornton et al., 2017). However, despite the huge number of yield-enhancing agricultural technologies existing in Africa, their adoption by farmers remains strikingly low explaining persistent productivity deficits and poverty among rural populations. One of the key factors explaining this substantial gap is related to the lack of farmers' access to the technical information and knowledge (TIK) about these technologies (Brown et al., 2018, 2017; Mardiana and Kembauw, 2020; Riungu et al., 2021). According to Jack (2013), technologies that are profitable will not be taken up without TIK about their existence, use, and profitability, especially when the technologies are new, technically intricate, or require precise implementation. On another side, women are well known to have less access to TIK, and to participate less to the awareness raising, training and on-farm demonstrations organized for technologies dissemination (Achandi et al., 2018; Diaz and Najjar, 2019; Duyen et al., 2021; Lamontagne-Godwin et al., 2017; 2018; Mujawamariya et al., 2022; Rice et al., 2019; Sutherland et al., 2021b;

[1] Africa Rice Center (AfricaRice), Cotonou, Benin
[2] School of Economy, Socio-Anthropology and Communication, FSA, UAC, Abomey-Calavi, Benin
[3] Africa Rice Center, Immeuble FOFIFA Ampandrianomby, Antananarivo, Madagascar
[4] National Agricultural Research Institute of Benin, Godomey, Benin

Corresponding authors:
Florent Mahoukede Kinkingninhoun Medagbe, Africa Rice Center (AfricaRice), Cotonou, Benin.
Email: fmedagbe@gmail.com; fmedagbe@outlook.com

Theriault et al., 2017; William et al., 2020). Complex and gender-biased technologies are specifically affected (Hörner et al., 2022). The non-consideration of gender issues in the development and dissemination of agricultural technologies (Addison et al., 2019), the lack of female extension agents (Lugman et al., 2018; Ragasa et al., 2013), time constraints faced by women compared to men (Kinkingninhoun Medagbe et al., 2020; Samee et al., 2015; Truong and Yamada, 2002), extension agents mainly talking to male farmers and household heads, who are mostly men (Agboh-Noameshie et al., 2013; Lamontagne-Godwin et al., 2018; Theriault et al., 2017; World Bank and IFPRI, 2010) are the main factors restricting women's access to extension services. Gender inequalities in access to technologies contribute to global hunger and food insecurity (Njuki et al., 2016; World Bank, 2009).

This paper adds evidence on the most effective extension approach for communicating complex and gender-biased TIK to both men and women. This issue has been largely understudied to date. Effective, inclusive and efficient transfer of TIK to farmers is crucial to ensure gender equity in technology access, technology adoption, agricultural development, food security and poverty reduction in rural communities. Linear extension approaches, in which technologies are generated by agricultural research and development and transferred to farmers through extension services for subsequent adoption, are still predominant in Africa (Moschitz et al., 2015). Most of them failed, not only to sustainably enable technology appropriation by farmers, but also to respond to gender inequality in extension service delivery (Williams et al., 2020; Lamontagne-Godwin et al., 2018). Farmer-to-farmer extension models have not been as successful as expected (Kondylis et al., 2016; Van den Berg and Jiggins, 2007). System approaches, in which farmers are important actors - like the Agricultural Knowledge and Information System (AKIS) - are being promoted and replacing the linear approaches (Cruz et al., 2021; EU SCAR AKIS, 2019). AKIS promotes an interactive model of networking systems, which integrate knowledge production, adaptation, advice and education (EU SCAR, 2012; Klerkx et al., 2012). On-farm demonstration is one of the activities embedded in an AKIS process to facilitate farmers' learning (Sutherland and Marchand, 2021a) and knowledge exchange between farmers and other stakeholders. Unfortunately, many studies in Europe found on-farm demonstrations to be engaging more male than female farmers and younger than elder farmers (Sutherland et al., 2021b).

This paper focuses on the smart-valleys technology extension. "Smart-valleys" is a promising rice technology recently developed and being disseminated for rainfed lowlands. On-farm demonstration was one of the key extension approaches used in its diffusion. It is an appropriate object for our study as the technology is complex, gender-biased and integrates features for Climate Smart-Agriculture (CSA). The study was carried out after the dissemination of Smart-valleys in many regions in Benin and Togo. This paper provides information on gender differences in Smart-valleys diffusion, on which extension approach in TIK communication is the most effective to both men and women, on the effectiveness of female extension agents compared to male extension agents and on the importance of women to women communication in improving female farmers access to TIK.

Material and methods

Description and dissemination of smart-valleys

Smart-valleys has been developed as a low-cost, participatory and sustainable lowland development approach by Africa Rice Center (AfricaRice) and its partners in 2012 and disseminated in West Africa. It is an innovation generated through an AKIS approach from fruitful discussions between researchers, extension services and lowland farmers during the participatory introductory and adaptation trials of the *Malay-Indonesian Sawah technology.* The new technology generated from this process is well adapted to African rainfed lowland farmers conditions. It consists in a participatory selection of inland valleys and in their development with the construction of irrigation and drainage infrastructures using local materials (Defoer et al., 2017). Smart-valleys is a land preparation, a water management, as well as a Climate Smart-Agriculture (CSA) technology (Figure 1). This makes Smart-valleys knowledge complex to be transferred. It requires a learning-by-doing approach through on-farm demonstrations. Yet, Smart-valleys being a lowland development approach, the main rice growing activities concern land preparation, which is a male dominated activity in Benin and Togo in lowland rice. Thus, the Smart-valleys know-how to be transferred to farmers is naturally easier to be handled by men than women. Therefore, Smart-valleys is a complex and gender-biased technology.

Smart-valleys was introduced and disseminated in Benin and Togo by AfricaRice in collaboration with its national inland valleys research partners, the Inland valleys research head office (DGR) in Benin and the Togolese Agricultural Research Institute (ITRA) in Togo. It has been tested on more than sixty sites in 2013 in West-Africa through on-farm demonstration and resulted into doubling rice yields for farmers (Africa Rice Center, 2015; Zwart et al., 2013). Five main types of actors or organizations intervened in the transfer: research teams, extension services, NGOs, lead-farmers and neighboring farmers. On-farm demonstration sites were located in the central-south, central-north and northern regions of each country. After the initial introduction of the technology by the research team, field technicians from extension services, NGO staff, and farmers' leaders were trained to disseminate the new technology further in other villages and regions.

Global research approach

An exploratory sequential mixed-methods design was used to collect the data used in this study, combining collection and analysis of qualitative and quantitative data.

Figure 1. Lowland plot developed with Smart-valleys approach.

Qualitative data were first collected and analyzed, followed by the quantitative data collection and analysis. Results from the first phase were used to design the questionnaire used in the second phase and added contextual meaning to the results from quantitative data analysis.

Data were collected from 2018 to 2019 in two West African countries: Benin and Togo (Figure 2). The sampling unit used was the lowland rice producer. A multistage stratified sampling method was used to select regions, municipalities, villages and lowland rice producers. Both Smart-valleys and non-Smart-valleys villages and farmers were randomly selected and investigated in each country. Three regions were selected in each country. In total, 15 villages were randomly selected and investigated in Benin against 18 in Togo.

The exploratory qualitative data were collected through focus group discussions (FGD) of about 15 farmers and key informants' interviews. Two separate sex-specific FGDs were conducted in each village: a male FGD and a female FGD. FGDs participants were purposively selected by the local facilitators in such a way to have a diversity of lowland rice farmers in a group (origin, age, social status, etc.). Furthermore, key informant discussions were conducted with some villages' authorities and rice farmers' associations leaders. The quantitative data were collected through a Computer Based Personal Interviews (CAPI) approach using Census and Survey Processing System (CSPro). In total, 1120 male and female lowland rice farmers were randomly selected and surveyed in the two countries, among which 486 were female farmers and 610 from Benin. The proportion of male and female farmers in the sample was based on the sex distribution of lowland rice farmers in each village.

Two main data analysis tools were used to compare the studied differences in parameters between the different sex: ANOVA test and Fisher's exact test The main indicator used here to assess the effectiveness of Smart-valleys TIK communication sources and means is the Smart-valleys mastery level. Farmers who are aware of Smart-valleys are informed about the new technology; they know about its existence and what it is about. However, farmers who master Smart-valleys are not only aware of it, but also know how to use it on their lowland plots, and this requires a learning-by-doing approach. Thus, Smart-valleys mastery level is the level of Smart-valleys know-how acquired by an individual farmer to develop his lowland plots.

Characteristics of the surveyed lowland farmers

The proportion of female in the sample was 43% and was higher in Benin (56%) than in Togo (28%) (see Table A1 in appendix). Most of the surveyed farmers (66%) are household heads with a higher proportion for male farmers than female farmers and in Togo than in Benin. Hence, most of female farmers were dependents. Most of the interviewed farmers were the main rice farmers in their households (87%). Lowland rice farmers were on average 42 years old with an average household size of 5.6 persons and 9.4 years of experience in rice farming. About 87% of farmers were married.

In terms of formal education, more male farmers were educated with higher schooling rate. Most of farmers (63%) belong to a farmers' association with a higher proportion in Benin and among male farmers. Also, 22% of them were among the leaders, with a higher occurrence among male farmers. Most of the lowland rice farmers received Smart-valleys TIK from contact persons speaking the same language as them. They trusted them (83%), had an at least good appreciation (86%) and a good understanding level (61%) of the training content. Male farmers had more often such a good understanding of Smart-valleys training content, which might be explained by the difference in their levels of schooling (Meinzen-Dick et al., 2010; Ragasa, 2012; Mungai et al., 2017).

Results

Gender analysis of the smart-valleys diffusion pattern

- *Is there any gender difference in Smart-valleys TIK communicators interventions?*: The research team

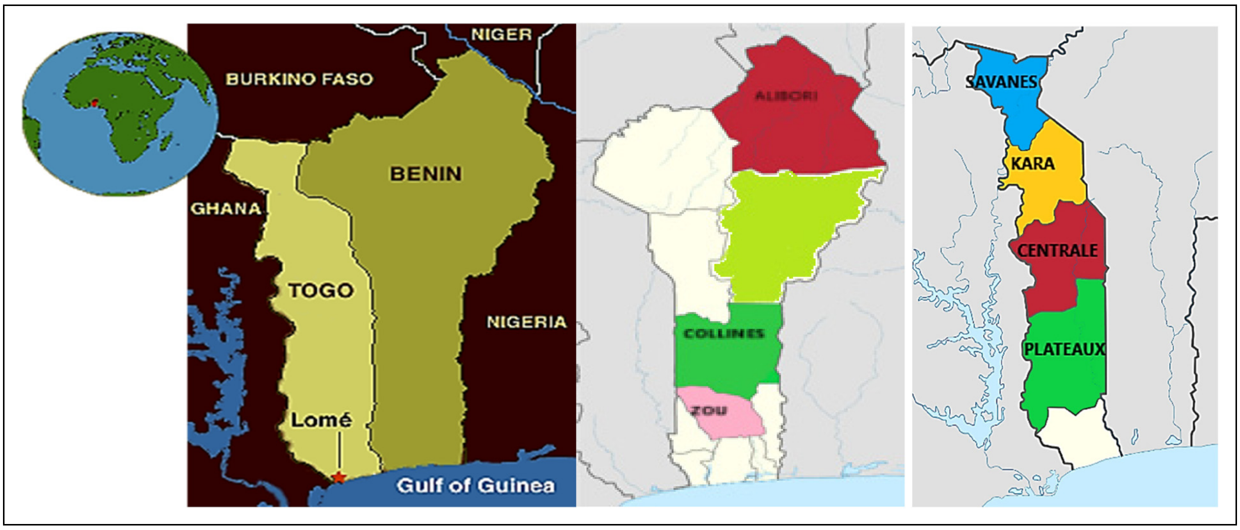

Figure 2. Geographical location of investigated countries and regions.

was the main Smart-valleys TIK communication source, informing 22% of the lowland farmers (or 66% of known lowland farmers[1]) followed by NGOs (4% or 13%), extension services and neighboring farmers (3% or 8% each) and lead farmers (2% or 7%) (Table 1). More farmers from Benin than Togo received Smart-valleys TIK from research team whereas more farmers from Togo than Benin received the TIK from extension services and neighboring farmers. While there was no significant difference between the proportion of male farmers and female farmers targeted by the other sources, the research teams communicated better with male than female farmers. This gender difference was mainly visible in Benin. NGOs informed more male than female farmers in Benin but more female than male farmers in Togo.

- *What were the main Smart-valleys communication means?*: Smart-valleys TIK were mainly communicated to farmers through awareness raising meetings (16% or 46% of known farmers) and on-farm demonstration (14% or 43% of known farmers) (Table 2). Both were more important means than oral training or discussion with farmers. The Smart-valleys TIK communication through media was almost inexistent. More male than female farmers participated in on-farm demonstration. They were majorly those hosting on-farm demonstrations fields. On-farm demonstration was the main media in Benin, against awareness raising meetings in Togo. More male farmers than female farmers were aware through both on-farm demonstration and awareness raising meetings in Benin while more female farmers than male farmers received the TIK during awareness meetings in Togo.
- Which means were used by the Smart-valleys TIK communicators?: Differences were observed in communication methods (see Table A2 in Appendix). Extension and NGOs field technicians used mostly on-farm demonstration while lead-farmers prioritized awareness meetings. Neighboring farmers informed their peers through awareness meetings, on-farm demonstrations and discussions. Note that discussions were mainly used by lead-farmers and neighboring farmers with their peers and they did not use oral training nor medias at all. Medias were mainly used by extension services. Extension field technicians and research teams in Benin and NGOs in Togo prioritized on-farm demonstration, while lead-farmers in both countries, NGOs in Benin, research field technicians and neighboring farmers in Togo used more awareness raising. Discussion with farmers (50%) and on-farm demonstrations (38%) were mainly used by neighboring farmers in Benin.
- *Are female communicators targeting more female farmers?*: Smart-valleys TIK was mainly communicated to lowland farmers by male-only (58%) or mixed-sex teams (40%) (Table 3). Only 2% of farmers were informed by female-only teams. This confirms the general very low proportion of female communicators used in technology diffusion. Male-only teams are more used in Benin than in Togo while mixed-sex teams are more used in Togo than in Benin. In Togo, female-only communicators were not used at all. Female communicators targeted higher proportion of female farmers than male communicators did. Female-only teams targeted higher proportion of female farmers and were more gender balanced while mixed-sex and male-only teams served higher proportion of male farmers. This means that the presence of female communicators in a team together with male communicators benefited male farmers.

Figures 3 and 4 present the sex of Smart-valleys communicators over sex of farmers in Togo in 2018[2] where higher proportion of farmers were informed by female-only

Table 1. Smart-valleys TIK communication sources and channels over sex and country (%).

Source/ Communicator		ALL	BENIN	TOGO
Research team	Total	*22*	*24**	*19*
	Female	*17****	*16****	*19*
	Male	*25*	*34****	*19*
Extension	Total	3	1***	5
	Female	2	1***	6
	Male	3	2*	4
NGO	Total	4	4	5
	Female	5	2***	10**
	Male	4	6*	3
Farmers leaders	Total	2	2	2
	Female	2	1	2
	Male	3	4*	2
Neighboring farmers	Total	3	1***	5
	Female	3	1***	6
	Male	3	1**	4

*p < 0.05, **p < 0.01, and ***p < 0.001. Source: AfricaRice/LADyD-FSA, ETES RICE Survey, 2018–2019

Table 2. Smart-valleys knowledge communication means over sex and country (%).

Communication means		ALL	BENIN	TOGO
Awareness meetings	Total	16	12***	20
	Female	14	10***	26*
	Male	16	15	17
Oral trainings	Total	3	2	4
	Female	3	2*	5
	Male	3	3	3
On-farm demonstration	Total	14	16**	11
	Female	10***	9	13
	Male	17	25***	11
Discussion with farmers	Total	1	1	1
	Female	1	1	0
	Male	2	1	2
Medias (Radio/TV)	Total	0.2	0.3	0
	Female	0.2	0.3	0
	Male	0.2	0.3	0

*p < 0.05, **p < 0.01, and ***p < 0.001. Source: AfricaRice/LADyD-FSA, ETES RICE Survey, 2018–2019

Table 3. Sex of smart-valleys TIK communication contact persons over sex and country.

Sex of communicator		ALL	BENIN	TOGO
Female only	Total	2	2	0
	Female	3* (55)	3	0
	Male	1 (45)	1	0
Male only	Total	58	63*	51
	Female	62 (40**)	66	58
	Male	55 (60)	62*	47
Both sexes	Total	40	35*	49
	Female	35* (31***)	31	42
	Male	44 (69)	37	53

*p < 0.10, **p < 0.05, and ***p < 0.01; The numbers in brackets are the relative shares of female farmers and male farmers served by each type of team

teams (5%). Results confirm that female communicators served higher proportion of female farmers compared to male communicators, even if they tended to communicate Smart-valleys TIK to more male farmers than female farmers in Togo. This confirms that using female-only communicators can effectively contribute to the reduction of gender inequality in access to agricultural technologies.

Results also reveal that more male farmers tend to share their acquired Smart-valleys TIK to their counterparts (more men than women) than female farmers (more women than men). This means that, even if female farmers were less likely to share their acquired Smart-valleys TIK, they shared it with more female farmers than male farmers. This reveals that women to women communication can effectively improve female farmers access to Smart-valleys TIK. This was confirmed in both countries and was more pronounced in Benin (88%) than in Togo (68%).

Effectiveness of smart-valleys TIK sources and means

Are the most effective smart-valleys knowledge communicators gender-equal?. Extension services (3.48) and research teams (3.45) field technicians were found to be the most effective

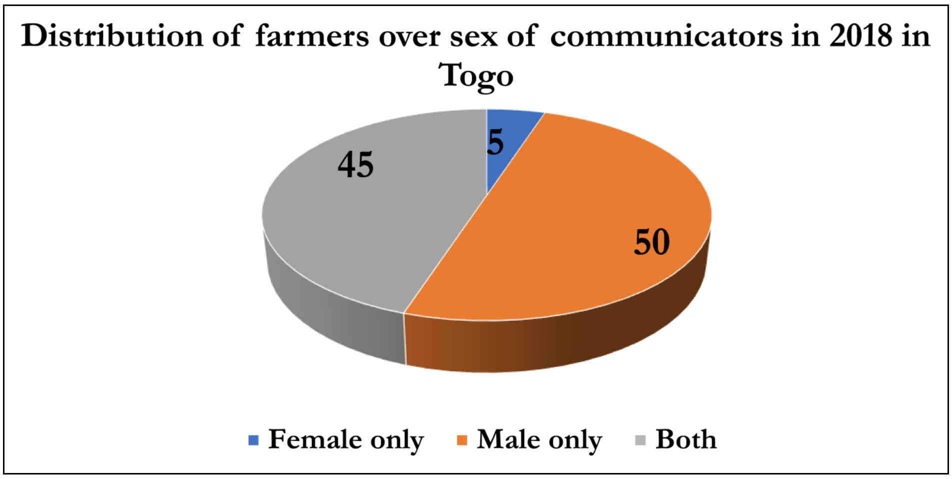

Figure 3. Distribution of farmers over sex of communicators in 2018 in Togo.

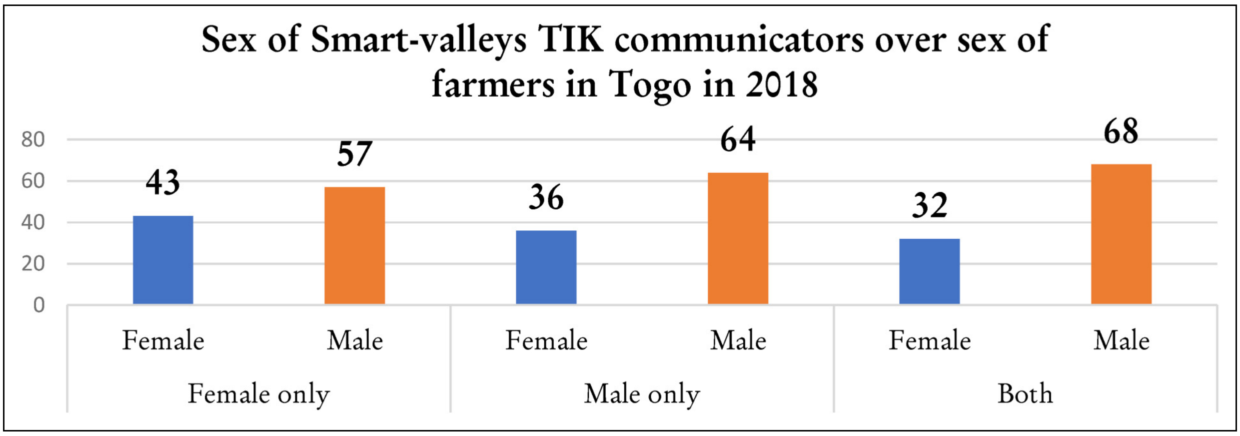

Figure 4. Sex of smart-valleys TIK communicators over sex of farmers in Togo in 2018.

sources in communicating Smart-valleys knowledge to lowland rice farmers (see Table A3 in Appendix). They were followed by NGOs, neighboring farmers and lead-farmers. NGOs were found to have helped the highest proportion of farmers to get at least an average level of Smart-valleys mastery.

Apart from NGOs, more male farmers than female farmers have at least an average level of Smart-valleys mastery among farmers targeted by the other sources. In addition, lead-farmers were found to be the communicators who helped both male and female lowland farmers to have the same level of Smart-valleys mastery. Therefore, NGOs technicians (in terms of mastery rate) or lead-farmers (in terms of average level of mastery) were the communicators that communicated Smart-valleys TIK more equitably to both male farmers and female farmers. Research team and extension technicians were not gender-equal in communicating Smart-valleys knowledge, but were found to have induced more gender inequality in terms of Smart-valleys mastery.

Is on-farm demonstration the most efficient means in communicating smart-valleys knowledge to both male and female farmers?. On-farm demonstration was the most efficient Smart-valleys knowledge communication mean (see Table A4 in Appendix). Awareness raising meetings followed and discussion with farmers was the least efficient. Even if more male farmers (67%) than female farmers (33%) benefited from on-farm demonstration, the same proportion of male farmers and female farmers attending on-farm demonstration trainings were able to have at least an average level of Smart-valleys mastery and have the same level of mastery. This is also true within countries. This indicates that, despite the relative lower level of understanding of the content of Smart-valleys trainings by female farmers due to their relative lower level of education compared to men, they were able to get the same level of Smart-valleys mastery through on-farm demonstrations. Therefore, on-farm demonstration is the best and the most effective communication approach to ensure equal access of both male and female farmers to Smart-valleys know-how.

Are women as efficient as men at communicating and teaching?. Female-only communicators were as efficient as male-only communicators and mixed-sex communicators in communicating Smart-valleys TIK (see Table A5 in Appendix). This means that women are as efficient as men at communicating and teaching technology information and

Table 4. Smart-valleys awareness and mastery rates in 2017 over sex and country.

Variables		ALL	BENIN	TOGO
Awareness of Smart-valleys	Total	30	32	27
	Female	25***	22***	33**
	Male	34	46***	25
Having at least an average level of mastery	Total	23	22	25
	Female	18***	13***	29**
	Male	27	32***	23
Average of Smart-valleys mastery level	Total	2.9	2.5***	3.4
	Female	2.6**	2.4***	3.0**
	Male	3.0	2.6***	3.5
Having at least an average level of mastery (among known farmers)	Total	66	64	69
	Female	61*	57	67
	Male	70	69	70

*$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$.

know-how. In other words, men are not better at communicating and teaching than women. Also, female-only contact persons and male-only contact persons were able to communicate Smart-valleys knowledge to both male and female farmers in an equitable way while male farmers trained by mixed-sex teams mastered better Smart-valleys than female farmers trained by them. This means that unisex (female-only and male-only) communicators teams are the best to ensure gender equity in complex and gender-biased technologies diffusion.

Access to smart-valleys TIK

Table 4 presents Smart-valleys awareness and mastery rates and levels over sex and country. In general, 30% of lowland farmers were aware of Smart-valleys and 23% had at least an average level of mastering Smart-valleys in 2017. More male farmers (34% and 27%) than female farmers (25% and 18%) were aware of and mastered Smart-valleys, respectively. Also, only 36% of aware farmers were female against 64% for male farmers while 34% of farmers who have at least an average level of Smart-valleys mastery were female against 66% for men. In addition, the average level of Smart-valleys mastery was 2.9 with higher value for male farmers (3.0) than female farmers (2.6). This means that male farmers mastered on average Smart-valleys better than female farmers. These results reveal that less female farmers had less access to Smart-valleys TIK than male farmers. This would limit their adoption, and therefore negatively affect their livelihood. In addition, 66% of farmers who were aware of Smart-valleys had at least an average level of Smart-valleys mastery, with higher proportion for male farmers than female farmers.

Even if only about the third of farmers who were aware of and mastered Smart-valleys were female in both countries, higher proportion of male farmers than female farmers in Benin were aware of and mastered Smart-valleys while higher proportion of female farmers than male farmers were aware of and mastered the technology in Togo.

In other words, male farmers had more access to Smart-valleys TIK than female farmers in Benin whereas female farmers had more access to Smart-valleys TIK than male farmers in Togo. However, male farmers have higher mastery level than female farmers in both countries. In other words, even if more female farmers mastered Smart-valleys in Togo, male farmers mastered better this technology than female farmers.

More farmers who were aware of Smart-valleys mastered it in Togo (93%) than in Benin (69%). Also, the average level of Smart-valleys mastery was higher in Togo than in Benin. This may yield to higher Smart-valleys potential adoption rate in Togo than in Benin. There was no significant difference between Benin and Togo in the level of Smart-valleys mastery although more farmers in Benin had benefited from on-farm demonstration trainings and had good understanding of the training content.

Discussions

The general gender inequality in access to Smart-valleys TIK with women having a lower access to Smart-valleys information as well as a lower mastering of the technology confirms the general gender gap in access to TIK in Africa and other developing countries (Agboh-Noameshie et al., 2013; FAO, 2018; Nyasimi et al., 2017; Ragasa, 2014; Ragasa et al., 2013; World Bank and IFPRI, 2010).

Women are less involved in agricultural technologies dissemination and participate less in awareness raising, training and on-farm demonstration sessions. This gender-bias in Smart-valleys TIK access is the result of the gender differences found in the Smart-valleys diffusion process. Indeed, research teams, the main Smart-valleys TIK communicators, communicated more to male than female farmers; more male farmers participated in on-farm demonstrations, the most effective communication mean. Most of the engaged communicators were men and targeted more male than female farmers. Female farmers also had a lower understanding of Smart-valleys trainings content due to their lower level of education compared to men (Meinzen-Dick et al., 2010; Ragasa, 2012). Field technicians involved in the TIK communication had not been trained to consider gender issues in their activities. This evidence is in line with observations made elsewhere in Africa. Ragasa et al. (2013) showed in a study conducted in Ethiopia that agricultural extension services often target men in their interventions and technology information diffusion, because they are influenced by the misconception that women do not devote much time to agricultural activities and that, in any case, the TIK provided to male farmers will eventually "filter down" from the head of the household (often male) to the other household members. The higher participation of male farmers to on-farm demonstration is in line with Sutherland et al. (2021b) who found, across Europe, that on-farm demonstrations were primarily attended by men.

The low proportion of female communicators in Smart-valleys diffusion also contributed to the lower access of female farmers to the TIK. It reflects the general low percentage of female extension agents in African countries (World Bank and IFPRI, 2010). According to Katungi et al. (2008) and World Bank et al. (2008), the majority of staff involved in TIK are men, and women in Africa are limited by social norms in communicating with men outside their families. Akeredolu (2009) identified five main reasons: (1) perception bias—the community's low perception of women's talents and potentials and perception of agriculture as a domain of men; (2) limited access to information about opportunities for further education; (3) limited opportunities that target professional women; (4) women reproductive roles and time constraints; and (5) other social, cultural, and religious barriers. In some cases, the lack of enthusiasm of some farmers, of women even, in working with and listening to female extension agents may be due to the fact that they do not perceive female communicators to be as good at farming and teaching, and pay less attention to their message and training (BenYishay et al., 2019). This gender gap in perception introduces inefficiencies in the transfer of TIK which can have important consequences on technology adoption, crop productivity and farmers livelihood. Yet, our findings show that female communicators were as effective as male communicators at communicating and teaching Smart-valleys technology information and know-how to farmers, both male and female. However, the presence of female communicators in a mixed team surprisingly exacerbated gender inequality, with male farmers benefiting more than female from such teams.

The lower level of Smart-valleys mastery among female compared to male farmers could be explained by the nature of the technology. Indeed, it is in itself a gender-biased technology, combining male dominated activities, especially the land preparation activity. Male farmers were more on-the-job during the practical on-farm demonstration than female farmers. Some women may have been reluctant in participating in the learning-by-doing phase, but many complained about the fact that they were mostly assigned the reproductive tasks during the practical on-farm demonstrations, fetching water and cooking food, so that they were not able to focus on the real training in the field. Time constraints generally faced by women because of their reproductive activities may also have prevented them to fully participate in the practical on-farm demonstration trainings (Kinkingninhoun Medagbe et al., 2020; Truong and Yamada, 2002). In addition, male farmers were found to have a better understanding of the trainings' contents than female farmers due to their higher level of formal education or schooling. As a result, male farmers mastered Smart-valleys better than female farmers. Furthermore, the significant contrasts in the average level of Smart-valleys mastery obtained from the cross-regional analysis reveals that it does not only depend on the participation in on-farm demonstrations and on the understanding of training contents, but on other factors as well, such as the willingness of farmers to acquire the technical knowledge and their personal involvement in the practical phases during the training sessions, their absorptive capacity (Liyanage et al., 2012) and their use of the acquired knowledge after the trainings. Since being aware of complex technologies like Smart-valleys is not enough for their adoption, it may not be expected for the 34% remaining known farmers to adopt the technology.

Gender inequalities in TIK transfer are real barriers for women to reach their full potential and this affects not only their productivity, food security and livelihood, but also national agricultural economies (FAO, 2013). According to the FAO (2011), Gates (2014) and World Bank et al. (2008), agricultural growth in many developing countries is compromised by gender constraints and unequal access to resources and productive opportunities, including new technologies. Gender inequalities in various economic sectors in many developing countries are still imposing real costs on society in terms of untapped potential in agricultural production, food security, economic growth and poverty reduction.

However, the higher access of female lowland farmers to Smart-valleys compared to male farmers in Togo contrasts with the common view. It confirms Zossou et al. (2016)'s findings in Benin of women having better access than men to formal sources of TIK (research, extension services and NGOs) in specific domains. This finding could be explained by the higher proportion of female farmers who attended awareness raising meetings in Togo, mainly those organized by NGOs field technicians. The contribution of the NGO "Women in Law and Development in Africa" (WiLDAF) working exclusively with women farmers groups upon the diffusion of Smart-valleys was key in this result. Indeed, after the demonstration trial and awareness fairs, WiLDAF disseminated the technology exclusively among female lowland farmers in the rice production areas in Togo in collaboration with ITRA, mainly in the southern region (AfricaRice, 2015). Despite the male-dominated nature of Smart-valleys, NGOs were able to efficiently communicate its knowledge to women in such a way that they were found to have the same mastery level as male farmers trained. Also, prior to this Smart-valleys dissemination, WiLDAF sensitized some rice production communities' leaders in Togo, including those of the target communities, for more gender equity in access to agricultural lands, what significantly improved the access of women to lowland plots. The contribution of NGOs in gender equality promotion in agriculture and other sectors has been recognized by many research works. The forefront roles played by NGOs are related to three main actions: 1) advocacy for a full recognition of women contribution in their households, community and societal development, and for equality or equity in access to productive resources, mainly lands (Hiremath, 2021; Muriisa, 2010; Srivastava and Austin, 2012), 2) education and training provided to women for their empowerment (Hiremath, 2021; Pokrzywa, 2018; Srivastava and Austin, 2012) and 3) facilitation of women access to productive resources for their economic empowerment (Hiremath, 2021; Srivastava and Austin, 2012). The higher access of women to TIK suggests that the continuous efforts of national and international organizations in gender mainstreaming actions and gender inequality reduction in the world are really resulting in a positive impact on marginalized people in general and on women in particular, for instance on their access to improved technologies; what would improve their livelihood. However, the women-focused gender mainstreaming interventions should frequently be evaluated to avoid a simple inversion of the gender inequality.

Female communicators teams were found to be more gender balanced and serve higher proportion of female farmers in Smart-valleys diffusion than male communicators or mixed-sex teams communicators did. This confirms Kondylis et al. (2016), World Bank and IFPRI (2010) and Zossou et al. (2016) who found that female extension workers serve a higher proportion of female farmers than male workers. Many studies conducted in Africa, Asia, and Latin America suggest the presence of female extension agents as an important factor for the participation of female farmers in extension activities. According to Due et al. (1997), 40% of women farmers in Tanzania preferred to work with female extension agents against 26% who preferred male extension agents. This preference was justified by the fact that female farmers were freer to discuss problems with female agents, who were better able to accommodate their time preferences for meetings than male agents. This reinforces the confidence that increasing the proportion of female agents in agricultural technology diffusion will effectively contribute to increase the proportion of female farmers having access to TIK, reducing gender inequalities in technology diffusion and improving technology adoption (Doss, 2001; Quisumbing and Pandolfelli, 2009).

In contrast, female farmers were less likely to share their acquired Smart-valleys knowledge with their counterparts than male farmers. This finding contrasts with Westermann et al.'s (2005) and Zossou et al. (2016) who found that the norms of reciprocity are more likely to operate in women's groups and that the capacity for self-sustaining collective action increased with women's presence and was significantly higher in women's groups. This contrast may be explained by the nature of Smart-valleys which is more male dominated technology and can be more easily handled and shared by men than women. Nonetheless, female farmers were found to communicate their acquired knowledge to more women than men. In other words, women to women communication improved female farmers access to Smart-valleys TIK. It was the case of the women extension volunteer (WEV) model in Ghana that confirmed that female communicators can be effectively used to facilitate female farmers' access to extension services and technologies through a peer-to-peer extension strategy (Hird-Younger and Simpson, 2013).

On-farm demonstration was identified as the best Smart-valleys TIK communication mean, not only for its effectiveness in TIK communication, but also for its gender equity, ensuring equal access of both male and female farmers. This finding could be explained by the various advantages of on-farm demonstration to facilitate an effective learning situation for farmers (Dar et al., 2019; Koutsouris and Zarokosta, 2020; Sutherland et al., 2021a; 2021b). Combined with good oral explanations, on-farm demonstrations allow farmers to have all the practical information on new technologies, practices or systems, but mainly to see them in a working farm (similar to their own), practice them, interact with scientists and extension workers on the field as well as with their peers (actively engaged in the practice and to whom they can relate), and get their doubts clarified themselves (Koutsouris and Zarokosta, 2020). They show how new technologies or innovative methods could work in practice in order to convince farmers to adopt them with increasing confidence (Kemp and Michalk, 2011). According to Sutherland and Marchand. (2021a), on-farm demonstrations facilitate to farmers experiential learning, peer-to-peer learning, transformative learning and network learning. All these advantages make on-farm demonstration especially suitable for technologies that are costly, complex, or require a major shift in operation (Bailey et al., 2006; Miller and Cox, 2006; Mujawamariya et al., 2022) like Smart-valleys. Lowland development technologies like Smart-valleys need to be mastered by farmers through an appropriate learning-by-doing process for technology know-how acquisition facilitating its adoption. Combining practical demonstrations to oral trainings in technology transfer process is always more effective, mainly in transferring information and knowledge of practical technologies like Smart-valleys (Bonwell and Eison, 1991; Coulshed, 1993; Dhehibi et al., 2020). According to Miller and Boud (1996), experience is indispensable for learning to occur.

Conclusion and recommendations

This paper aimed to provide evidence on the most effective extension approach for communicating information and knowledge on complex and gender-biased technologies to both men and women. Smart-valleys TIK was mainly communicated to farmers by research teams through awareness raising meetings and on-farm demonstrations, but extension services and research team were found to be the most effective communicators to lowland farmers. Findings show a gender inequality in Smart-valleys TIK communication to farmers. Male lowland farmers still had a better access to the TIK than female farmers, confirming the common view. However, it is possible to ensure gender equality in agricultural TIK transfer, even in case of complex and gender-biased technologies if specific gender mainstreaming and gender equity actions are implemented during technology diffusion. On-farm demonstration was identified as the most effective Smart-valleys TIK communication approach, and also the communication mean that ensured gender equity in access to TIK of both male and female farmers. Female communicators teams were found to be more gender balanced and serve higher proportion of female farmers in Smart-valleys diffusion than male and mixed-sex teams. Even in farmer-to-farmer communication, women to women communication improved female farmers access to Smart-valleys TIK. Female communicators were found to be as efficient as men at communicating and teaching technology information and know-how, but only few were used in Smart-valleys TIK transfer.

In this context, it is important to adopt on-farm demonstration combined with oral explanations embedded in the global AKIS approach (EU SCAR AKIS, 2019; Cruz et al., 2021) as the main approach for the diffusion of complex and gender-biased technologies in general, and for the Smart-valleys diffusion in particular. Awareness raising meetings can be organized to inform the target population and share information on the technologies, but on-farm demonstration sessions should be organized as the main activity to transfer the TIK. Both male and female experienced field technicians recruited and organized in unisex teams should be trained upon on-farm demonstrations (Adamsone-Fiskovica et al., 2021; Richardson, 2003; Sutherland and Marchand, 2021a), not only on technical aspects of the technology transfer, but also on gender key concepts and gender integration including Lukes (2005) three faces of power for inclusive Smart-valleys TIK communication. NGOs supporting rice producing communities, mainly in lowland rice production and gender equality advocacy, could also be involved. Because of the gender bias of Smart-valleys, specific gender mainstreaming and gender equity actions should be undertaken to encourage women to participate in on-farm demonstration sessions, to ensure that they are fully involved on-the-job during these learning-by-doing sessions. Both male farmers and female farmers plots should be chosen as the demonstration sites to facilitate the implication of women. On-farm demonstration should be organized at village level as usual to facilitate women attendance. It is also important to train lead farmers, both male and female, in how to organize on-farm demonstration to facilitate farmer-to-farmer diffusion and inclusivity. According to Sutherland et al. (2021b), when farmers organize on-farm demonstrations, these events are more likely to be attended by women and younger farmers.

An extension of Smart-valleys dissemination to the other lowland rice growing areas in West-Africa in the conditions recommended above will reduce gender inequality in Smart-valleys diffusion, improve lowland farmers access to and adoption of this lowland development technology, their rice productivity and rice production, and therefore improve lowland rice farmers livelihood.

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ORCID iDs

Florent Mahoukede Kinkingninhoun Medagbe https://orcid.org/0000-0001-7824-5719

Kossi Nounagnon Augustin Aoudji https://orcid.org/0000-0001-7405-7630

Supplemental material

Supplemental material for this article is available online.

Notes

1. 'Known lowland farmers' are lowland farmers who are aware of or have been informed about the new technology in opposition to farmers who have never been informed about it. They represent 30% of the surveyed sample.
2. *In Togo, apart from 2017 data used in this study, 2018 data were also collected. This was not the case in Benin because the data were collected in Benin in 2018 and in Togo in 2019. 2018 key target data were not available at the time of the survey in Benin.*

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