Are smallholder farmers involved in the process of agroecological innovations? Evidence from vegetable farmers in the Republic of Benin

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Abstract. Although recent studies show that agroecological innovations are effective techniques that ensure sustainable food production, their development and adoption are less well-known. This study aims to understand how agroecological innovation occurs in vegetable farming in Benin. Data were collected from 300 randomly selected households in three main vegetable-producing areas in Benin. Among agroecological vegetable innovations developed over the last 10 years, about 49% are outside innovations that farmers know of, 31% are outside innovations that farmers are not familiar with, and 22% are identified by farmers as local innovations. Innovations are better known in municipalities where farmers have more formal education, access to extension services, and access to credit. Farmers' priority innovations relate to integrated soil fertility, pest control, and water management. Promoting these practices would be an effective way towards achieving sustainable food security. Many farmers (82%) were not associated with the innovation process. Agroecological stakeholders need to go beyond traditional forms of top-down intervention and involve farmers in the innovation process.

Keywords: vegetable agroecology, farmers' involvement in the innovation process, sustainable vegetable farming.

Introduction

Agriculture is a primary source of livelihood, providing household income and food security for most of the people in West Africa (Osabohien et al. 2019). Vegetable production is of great economic importance in the agricultural sector and plays a crucial role in nutrition, human health, food security and poverty reduction in West African countries (Nordey et al. 2017; Souleymane et al. 2021). Despite the prominence of vegetable farming in smallholder farmers' livelihood improvement in Benin, its production makes intensive use of agrochemical fertilizers and pesticides (Williamson et al. 2008; Zoundji et al. 2018). Excessive use of synthetic agrochemicals in the country negatively impacts effectiveness of pest control, soil improvement and compromises the quality of vegetables, with dangerous effects on human health and the environment (Assogba et al. 2022; El-Sheikh et al. 2022). In addition, the agriculture sector, particularly vegetable production, are being called upon to adapt to meet environmental challenges, climatic disruptions and societal demands for more and higher quality food (Côte et al. 2019). These challenges call for rapid transitions in the agricultural systems to ensure food security and improve smallholder farmers' livelihoods (FAO 2018a; Abegunde et al. 2019).

In the face of such global trends, agroecological farming, which improves food production and farmers' livelihood, offers a new paradigm of sustainable agricultural and food systems by addressing societal expectations, food and health emergencies and global environmental concerns (Caron et al. 2018; Tittonell et al. 2020). Agroecological practices include pest and disease control, soil fertility management, and biodiversity conservation, while paying more attention to climate change adaptation (Rehman et al. 2023). Vegetable production in Benin (which employs thousands of people) is highly dependent on agrochemicals and must adopt agroecological practices to become more resilient and sustainable (Yarou et al. 2017; Zoundji et al. 2018).

Agroecology is a promising pathway for sustainable vegetable production. However, to meet sustainable production challenges, more attention should be paid to co-creating knowledge and innovation with farmers rather than transferring information with a top-down model in agricultural extension (Loconto et al. 2017; El Bilali 2019; Utter et al. 2021). Knowledge co-creation, which refers to the process of joint innovation production between industry, research and other stakeholders, is crucial for promoting sustainable practices (OECD 2021). Therefore, knowledge co-creation is a powerful mechanism to develop and generate innovation, which is an important component in sustainable vegetable production (FAO 2018b). However, research on innovation development has been limited, even though many studies have been carried out on the adoption of agricultural innovations (Meadow et al. 2015; Weyori et al. 2018).

This study aims to understand how agroecological innovation occurs in vegetable farming in Benin. In doing so, we first examined existing documentation by identifying agroecological innovations developed in vegetable farming in the previous ten years. Second, we evaluated farmers' knowledge of the identified innovations. Third, farmers' involvement in the development of innovations has been analysed. We then discussed opportunities and challenges for knowledge co-creation for agroecological innovation and concluded with recommendations for moving forward.

Theoretical framework

Innovation is an idea, practice, behaviour, or artefact that is perceived as being new by the adopter. Its success depends on how well it evolves to meet the needs of more demanding people (Eservel 2014). A good way to achieve this is to make users into partners in a continuous process of development since innovation does not just happen, but it is socially constructed (Beausoleil 2018). For innovation to happen, it is necessary to develop management systems and explore subjective capital, which is knowledge, and can be applied to the use of organisational resources and allow a new production process (Musiolik et al. 2012). Innovation development processes can vary by organisation or enterprise. They can be influenced by other factors such as the sector of activity, the size of the organisation, and social or cultural values (Meijer et al. 2015; Beausoleil 2018, Dean & Schultz, 2023). Many authors mentioned that innovations generally occur through two phases. An "initiation phase" involves all activities relating to problem perception, information gathering, attitude formation and evaluation, and resource attainment leading to the decision to adopt the innovation. An "implementation phase" consists of all actions pertaining to modifications to the innovation and organisation, initial utilization, and continued use or discontinued use (Rogers 1983; Staw 1990; Damanpour 1991, Beausoleil 2018).

Achterkamp & Vos (2006),mentioned that the innovation process is comprised of three periods: 1) an "initiation period" that covers events that set the stage for launching the efforts of developing the innovation; 2) a "developmental period" that comprises activities and efforts undertaken to transform the innovation idea into a concrete reality; and 3) an "implementation period" when the innovation is adopted, until it is eventually abandoned. In the innovation development process, Bhaskaran (2006) and Acemoglu et al. (2022) distinguish between radical innovations (creative/advancement in knowledge and consequent development of new products and processes) and incremental innovation (ongoing improvement to produce, process, and service). The process of innovation is a sequence of activities involving an intention to solve a specific problem in a particular context, the development of something perceived as new, and the adoption of the new element over time (Beausoleil 2018). However, farmers' knowledge, attitudes and perceptions are a determinant factor in the decision-making process of innovation adoption (Meijer et al. 2015; Zossou et al. 2020). The same authors highlighted that farmers' perception refers to the views that they hold based on their needs, experiences, knowledge and expectations of profitability. This perception changes over time as the farmers gain new experiences and knowledge (Trinh et al. 2023).

Research Method

The study was conducted in the municipalities of Malanville, Grand-Popo and Sèmè-Podji, which are the main urban and peri-urban areas of vegetable production in Benin (MAEP 2017), located in the extreme northeast, southwest and southeast of Benin respectively. In the north, the municipality of Malanville extends between 11.5° and 12° latitude from North to South over 50 km and from East to West over 60 km with a Sudano-Sahelian climate: a rainy season from May to October and a dry season from November to April (PDC Malanville 2017). It is in the Niger River Basin, which offers an important opportunity for agricultural production. The municipalities of Grand-Popo and Sèmè-Podji are in the south of the country and belong to the Guinea zone, which extends from the Atlantic Coast and stretches between 1°45' and 2°24'E and 6°15'and 7°00'N to the west and 6°15' and 7°30'N to the east (Akoègninou et al. 2006). Their subequatorial climate has two rainy seasons (April to July and October to November).

A scoping grey literature review (Paez 2017; Zhang et al. 2021) was carried out to inventory vegetable agroecological innovations developed over the last ten years in Benin. Then, data were collected from December 2022 to January 2023 in three villages from each municipality. Nine villages were selected in the three study municipalities based on the following stratifying criteria: (a) the importance of vegetable growing, (b) the village's experiences in agroecological vegetable farming and their willingness to participate in the study, and (c) the village accessibility. The sample unit of this study was the household, which is represented by the vegetable farmer, who is a household head, or someone delegated by the household head. Using lists of all vegetable farmers in each village obtained from the Territorial Agency for Agricultural Development (ATDA), our sample included 300 households selected through a random sampling technique (Table 1).

Table 1. Research sample structure

Municipalities	Villages or sites	Number of farmers	Total
Sèmè-Podji	Vimas	46	100
	Cojemas	22	
	Jinukun	32	
Grand-Popo	Grand-Popo 1	33	100
	Grand-Popo 2	30	
	Grand-Popo 3	37	
Malanville	Monkassa	39	100
	Toumboutou	34	
	Bodjecali	27	
Total		300	300

Data were collected in two main phases. First, an exploratory study was conducted by using Focus Group Discussions (FGD); with 27 FGD conducted, i.e. three focus groups per village (one each for youth, women, and men vegetable farmers). A FGD included a maximum of ten farmers and a minimum of eight in accordance with Greenbaum (2000) who recommended seven to ten participants for a FGD. The FGDs were conducted to confirm and complete the grey literature review on the vegetable agroecological innovations developed over the last ten years. An innovation that was "not known" in at least one of the three municipalities was discarded. An innovation is "known" when farmers experiment with or use an exogenous innovation and can easily and confidently describe it to their neighbours; otherwise, it is an "unknown" exogenous innovation. "Local innovations" are those that farmers describe as their own, can confidently explain the innovation accurately and have applied it. During the FGDs, a score (0 to 2) was attributed to each innovation, based on farmers reaching a consensus about the degree of importance of an innovation. The innovations that received the highest score were classified as priority innovations. These innovations have all gone beyond the experimental stage and have systemic effects and transformative potential.

This exploratory phase provided initial information on the innovations, their nature, the initiator, the actors involved in their promotion, socio-economic factors and the level of adoption. Information was also gathered on the constraints, strengths, threats, and assets related to the use of the innovations. The second phase consisted of data collection at the individual level based on a structured questionnaire survey implemented using Kobocollect software (Chaudhary et al. 2023). Data were collected on vegetable farmers' socio-economic characteristics such as gender, experience in vegetable farming, area under cultivation, age, level of education, household size, access to extension services, access to credit and access to land. For each innovation, farmers were asked about their level of knowledge, involvement in their development, year of first use, categorization of the innovation, other actors involved in their development, environmental, physical, social and economic transformations that led to the innovation, and actors involved in their dissemination, promotion, or scaling up.

A formal method in ethnography, which was based on thematic trends in farmers' statements (Sanjek 2000), was used to analyse the qualitative data. Quotes have been used to bring vegetable farmers' views into the analysis. Econometric analysis of the quantitative data was used to determine the socioeconomic factors influencing the knowledge of agroecological innovations. The Poisson regression was used to identify the determinants of farmers' involvement in innovation (Olutumise 2023). Quantitative and qualitative analyses were based on the innovation development and adoption theory.

Results

Vegetable farmers sociodemographic characteristics

Table 2 presents the sociodemographic characteristics of households involved in this research. Of the 300 survey respondents, most (52%) were young farmers between 18 and 40 years-old, with an average age of 29. About 48% were older farmers (41-60 years). Four-fifths were male (81%). Both genders are involved in vegetable farming, and almost all respondents (97%) were married with an average household size of about seven persons. Most (58%) respondents were members of farmers' associations. About two-thirds (60%) of respondents had 5-10 years of experience in vegetable farming and most (60%) had no access to credit. About two-thirds (61%) of respondents had no formal education, and most were illiterate. Surveyed farmers had limited access to government and private agricultural extension services (36%) and rely more on informal networking (relatives, peers, other farmers) and farmers' organisation (100%).

Table 2. Vegetable farmers' sociodemographic characteristics (%)

Variables	Characteristics	Municipalities			All
		Sèmè - Podji	Grand Popo	Malanville	
Age (in years)	18-40	72	54	31	52
	41-60	28	46	69	48
Gender	Female	17	27	14	19
	Male	83	73	86	81
Marital status	Married	95	97	98	97
	Single	1	2	0	1
	Widowed	4	1	2	2
Household size (people)	1-5	30	20	20	23
	6-10	70	80	80	77
Education	No formal schooling	42	55	85	67
	Primary school level	30	34	12	25
	Completed 1st level of secondary school (4 years)	16	7	3	9
	Completed 2nd level of secondary school (3 years)	8	3	0	4
	Any university training	4	1	0	2
Member of farmers' association	Yes	81	56	38	59
Experience in vegetable growing (year)	< 5	25	24	30	26
	5-10	66	56	58	60
	> 10	9	20	12	14
Access to extension services	Yes	48	39	21	36
Access to information via networking & farmers' association	Yes	100	100	100	100
Access to credit	Yes	58	41	21	40

n=300

Vegetable farmers' knowledge of agroecological innovations

Figure 1 and Table 3 present farmers' knowledge of innovations by study area. In the three municipalities studied, an average of 49% of the innovations were known, 31% were not known and 22% were local. Innovations were better known (60%) in the municipality of Sèmè-Podji, followed by Grand-Popo (48%) and Malanville (40%). (Table 3). However, in Malanville where fewer innovations were known, farmers identified more local innovations (32%), while Sèmè-Podji knew more exogenous innovations, but fewer local ones (8%).

Figure 1. Farmer knowledge of agroecological innovations

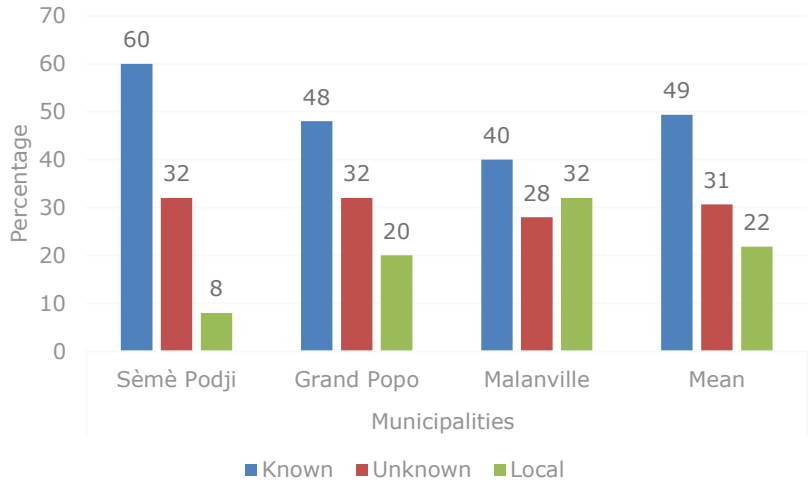


Table 3. Vegetable farmers' knowledge of vegetable agroecological innovations

Domains	Description	Known/ Unknown/ Local			Nature
		Sèmè Podji	Grand Popo	Malanville	
Certified seeds	1- Certified vegetable seeds	✔	✔	✔	ǂ
Integrated soil fertility management	2- Crop rotation with a cover crop (Mucuna sp.)	✔	✔	✘	ǂ
	3- Crop rotation	✔	✔	✔	ǂ
	4- Fallow land made up of wild leguminous plants that indicate soil fertility	✔	✔	✔	ǂ
	5- Ploughing preceded by weeding (degradation of grass for fertilization)	✔	✔	✔	ǂ
	6- Spreading animal manure as basal dressing (cow dung, poultry or rabbit droppings)	✔	✔	✔	ǂ
	7- Making compost from organic waste and crop residues	✔	✔	✔	ǂ
	8- Use of clay sands and termite mounds	+	+	✘	ǂ
	9- Making compost from water hyacinth	✘	+	✘	ǂ
	10- Liquid plant growth stimulant (cow urine, biogas solutions or fermented manures)	✘	+	✘	ǂ
Integrated pest management	11- Electric motor sprayer	✔	+	+	ǂ
	12- Alternative pest control and fertilization techniques (push-pull, legume crops)	✔	✔	✔	ǂ
	13- Making bio pesticides from neem, garlic, chilli, onion, pepper, orange leaves, papaya leaves, ginger, fruit juice, kitchen ash, soap	✔	✔	✔	ǂ
	14- Pest control techniques (use of mosquito nets, regular weeding, crop association, repellent plants)	✔	✔	✔	ǂ
	15- Crop association and biological control	✘	✘	✔	ǂ
Harvest/ post-harvest	16- Harvesting onions before the leaves are dry	✘	+	+	ǂ
	17- Traditional onion preservation method	✘	✘	+	ǂ
	18- Harvesting of lettuce, carrot, onion or by cutting the secondary stems with a knife (moringa, amaranth, etc.)	✔	✔	+	ǂ
Marketing/ certification	19- Direct sales from farmers to consumers	✔	✘	+	±
	20- Participatory certification system for organic products	+	✘	✘	±
	21- Creation of the onion marketing platform	✘	✘	+	±
	22- Organisation of group sales	✘	✘	+	±
Water management	23- Gravity irrigation from a water source	✘	✘	+	ǂ
	24- Irrigation kits (perforated band, turnstiles, sprinkler irrigation, etc.) for watering	✔	✔	✘	ǂ
	25- Adaptation of motor pump to run on butane gas for irrigation	✔	✘	✘	ǂ

✔= Known (very knowledgeable): farmer can confidently explain the innovation accurately & has applied it; ✘= Unknown (No knowledge), farmer is not aware of the innovation; **+**= Local innovation: Respondent can confidently explain the innovation accurately and has applied it; **ǂ** = Technical innovation; **±** = Organisational innovation.

Importance of agroecological vegetable innovations

Farmers ranked the innovations according to their importance in vegetable farming. Among the 25 agroecological innovations developed over the last 10 years in vegetable farming, five innovations received similar ratings for importance by farmers in each municipality (Table 4). This means that all farmers agree on the average rank assigned to each of these priority innovations. The five important agroecological innovations in the municipality of Sèmè-Podji were: spreading animal manure as a basal dressing, making compost from organic waste and crop residues, making bio pesticides, irrigation kits (using flat perforated hose, turnstiles, sprinkler irrigation) and adaptation of a motor pump to run on butane gas for irrigation. In the municipality of Grand-Popo, the five most important agroecological innovations recognized by the farmers were: spreading animal manure as a basal dressing, making compost from organic waste and crop residues, making bio pesticides, electric motor sprayer and irrigation kits (e.g. perforated band, turnstiles, sprinkler irrigation). In the municipality of Malanville, the five main agroecological

innovations identified were: spreading animal manure as a basal dressing, making compost from organic waste and crop residues, making bio pesticides, electric motor sprayer, and gravity irrigation from a water source.

The top three priority innovations (spreading animal manure as a basal dressing, making compost from organic waste and crop residues, making bio pesticides) were the same in all study areas. The fourth most important innovation was the same in the municipalities of Grand Popo and Malanville.

Table 4. Importance and initiators of agroecological innovations

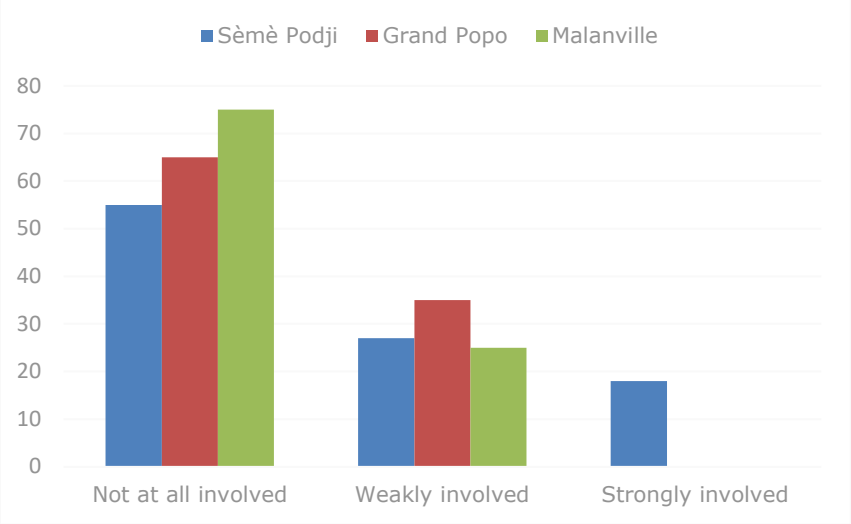
Rank	Name	First use	Adoption level	Initiators/ actors involved
Municipality of Sèmè-Podji				
1st	Animal manure as a basal dressing	Many years ago	Large scale	Ministry of Agriculture (MINAG) projects Farmers
2nd	Making compost from organic waste and crop residues	2008	Large scale	Research centres NGOS
3rd	Making bio pesticides	2011	Large scale	NGOs
4th	Using irrigation kits	2018	Large scale	MINAG projects NGOs
5th	Adaptation of motor pump to run on butane gas for irrigation	Many years ago	Large scale	Farmers
Municipality of Grand-Popo				
1st	Animal manure as a basal dressing	Many years ago	Large scale	NGOs Farmers
2nd	Making compost from organic waste and crop residues	2017	Large scale	MINAG projects Farmers
3rd	Making bio pesticides	2012	Large scale	NGOs Research centres
4th	Electric motor sprayer	2019	Large scale	MINAG projects
5th	Using irrigation kits	2018	Large scale	MINAG projects
Municipality of Malanville				
1st	Animal manure as a basal dressing	Many years ago	Large scale	MINAG projects Farmers
2nd	Making compost from organic waste and crop residues	2015	Large scale	NGO
3rd	Making bio pesticides	2012	Large scale	NGOs Research centres
4th	Electric motor sprayer	2019	Large scale	Farmers
5th	Gravity irrigation from a water source	Many years ago	Large scale	Farmers

Farmers' involvement in the agroecological innovations process

In the three municipalities studied, 65% of farmers were not involved in the agroecological innovation development process. On the other hand, 29% of farmers were weakly involved and only 6% were strongly involved in the agroecological innovation development process. This showed the low rate (36%) of agroecological vegetable innovations identified and developed over the last 10 years. Figure 2 presents the level of farmers' involvement in the agroecological innovation development per study area. Many farmers were not all involved in the development of innovations: 55% in Sèmè-Podji, 65% in Grand-Popo and 75% in Malanville.

Nevertheless, 32%, 22% and 12% of farmers believed that they were moderately involved in innovations development, respectively, in Sèmè Podji, Grand Popo and Malanville. Thus, except for 18% of respondents from Sèmè Podji, the others were not associated with the "initiation phase" or research, which is essential for innovation adoption.

Figure 2. Farmers' involvement in agroecological innovations development



Factors determining farmers' involvement in the innovation process

The data collected allowed the use of the Poisson regression model to gain insight into the factors that may influence vegetable farmers' involvement in agroecological vegetable innovation development. The results of the Poisson regression show that the model is globally significant (Table 5). There most statistically significant relationships with the farmers' decisions to be involved in agroecological vegetable innovation development were with group membership ($p \leq 0.001$) and access to agricultural credit ($p = 0.002$). A statistically significant relationship was found between farmers' access to research and extension institutions ($p \leq 0.05$) and their decisions to participate in the innovation process. Farmers' level of education and perception of participation in the research project ($p \leq 0.01$) may also have been linked to their decisions to be involved in agroecological vegetable innovation development.

Table 5: Drivers of farmers' involvement in innovation development process

Independent variables	Coefficient ± SE	Probability
Group membership	4.924±1,241	0.000***
Agricultural credit access	1.975±0,307	0.002***
Access to research & extension institutions	1.950±0,864	0.023**
Level of education	0.916±0.488	0.052*
Perception to participate in the research projects	0.994±0,621	0.059*
Age	-0.040±0.048	0.396
Gender	1.018±0.839	0.221
Experience in vegetable growing	0.029±0.051	0.579
Market access	0.221±0,826	0.791
Constant	-4.556±2,081	0.029

n= 300; Log likelihood = -159.4; Pseudo R^2 = 0.28; Prob > chi2 = 0.0000
* = $p \leq 0.01$; ** = $p \leq 0.05$; *** $p = \leq 0.001$

Discussion

This research showed that both genders were involved in vegetable farming, but it is a male-dominated activity in the study areas. INSAE (2016) also found that there were more men than women in the agricultural sector in Benin. Most of our sampled farmers had no formal education and were illiterate. Mockshell and Villarino (2019) also showed that farmers with little formal education levels, have limited ability to acquire some forms of new agricultural knowledge. In addition, surveyed farmers have limited access to government and private agricultural extension services and rely more on informal networking (relatives, peers, other farmers) and farmers' organisations. This is supported by Zoundji et al. (2016) and Zossou et al. (2020) who found that farmers mostly rely on social networks to meet their information needs. However, farmers' access to more creative or radical information mainly depends on the agricultural extension services (Zoundji et al. 2020; Tekeste et al. 2023) and poor access to extension limits knowledge co-creation for agroecological innovation. The NGOs Access Agriculture, JINUKUN Copargen,

Hortitech Development, Organisation Béninoise pour la Promotion de l'Agriculture Biologique (OBEPAB) and the research centre International Institute of Tropical Agriculture (IITA) were the main sources of information on vegetable agroecology in Benin.

Our study found that innovations were better known in the municipalities where farmers had higher socio-economic characteristics such as education level, access to extension services, access to credit, and membership in farmers' associations. Many other authors (Barnes et al. 2019; Zossou et al. 2020; Yegbemey et al. 2021) have also shown that socio-economic characteristics influence farmers' knowledge of innovations. Farmers with low education levels and lack of access to advisory services often have limited ability to efficiently adopt and implement agroecological innovations (Mockshell and Villarino 2019; D'Annolfo et al. 2021). When farmers have poor access to outside information, they try to find solutions to their problems, since agricultural innovation is principally concerned with the need for change, and the desire for change influences farmers' knowledge of innovations (van der Veen 2010; Okonta et al. 2023). Learning for innovation is best accomplished when farmers experiment from a position of real need rather than being told what outsiders think their need is (Zoundji et al. 2016). Furthermore, as innovations were adopted according to the problems they solved, farmers in Malanville have developed incremental innovations (ongoing improvement to produce, process, and service) that enable them to solve problems related to harvesting and marketing onions. Innovation does not just happen; it is socially constructed (Beausoleil 2018). Thus, vegetable farmers construct mechanisms for developing new ideas through their social or cultural practices. This type of innovation is an important strategic tool for the success of small and medium-size organisations that operate in competitive markets (Bhaskaran 2006).

The top three priority innovations for agroecological vegetable farming mentioned by farmers were all technical (certified vegetable seeds, crop rotation with a cover crop of Mucuna, and crop rotation) (Table 3). These innovations are easy to put into practice and farmers were more confident about the benefit they would get by adopting them. Rogers (1995) also noted that farmers' innovation adoption depends mainly on the relative advantage, compatibility, complexity, trialability and observability of the technologies. In addition, respondents' need for innovation is generally driven by the farming environment, which is heavily influenced by water issues or rainfall uncertainty, crop pests and soil fertility problems. The areas of innovations also reflect the efforts of agricultural research and development projects. Thus, priority innovations identified by respondents were related to three main categories: integrated soil fertility management, integrated pest management and water management (ISFPWM) practices, which have been extremely effective in controlling pests and diseases, improving soil fertility, increasing productivity, achieving sustainable agriculture, and increasing household income in many African countries (Adolwa et al. 2019; Ndegwa et al. 2023). Hence, promoting ISFPWM practices would be an effective way towards agroecological farming and achieving sustainable food security and nutrition.

Research institutions, development projects and local NGOs introduced these innovations, which can be described as exogenous, even though some were inspired by local practices. Thus, the main actors in the innovation development process were research organisations, NGOs and producers involved in experimentation, or development projects with the farmers groups they support.

This research found that most farmers were not involved in the agroecological innovation development process. A few farmers were weakly involved and very few were strongly involved in the agroecological innovation development process. Among the three municipalities studied, only in Sèmè-Podji were some farmers strongly involved in innovation development. The following testimony of a vegetable farmer in Sèmè-Podji explained how he was involved in compost making as a participatory research activity:

> As you may know, vegetable farming in this area of Sèmè-Podji is faced with declining soil fertility, which was a serious problem for us. Then, about eight years ago, I learned how to make compost, which is an ecological method of recycling organic waste. I was one of 13 presidents of vegetable farmers' association who have been trained on this innovation, in my field here, by three "akowè" (scientists) from the National Institute for Agricultural Research of Benin (INRAB) in collaboration with our "glégan" [an extension worker].

Low involvement in innovation development may sometimes lead to the non-adoption of certain innovations. Thus, strengthening the interactions between stakeholders, organisations and their social, cultural and political structures through network building, social learning, and negotiation would be a prominent way to trigger innovation (Leeuwis and Aarts 2011). Furthermore, by relying on the theories of adult learning, referred to as 'learning by doing' (Kolb et al. 1984), this case shows that vegetable farmers' conclusions that are based on their personal experiences,

more significant perceptions and values tend to have a greater impact on innovation development and adoption than insights derived from policy makers.

A few farmers were moderately involved in the development of technological vegetable innovations. Thus, many farmers were not associated with the research, which may decrease innovation adoption. Therefore, agroecological stakeholders in general, and policy makers in particular need to go beyond traditional forms of agricultural extension based on top-down interventions which are outdated and inefficient (Wijeratne and De Silva 2023) and so less able to cope with the current challenges and the dynamic demands of agriculture. Moving from a transfer of technology to a demand-driven approach has been accompanied by many participatory extension methods implemented through various institutional arrangements (David and Asamoah 2011). Thus, participatory approaches with much more engagement of farmers, policymakers and academia can better promote and sustain agroecological farming systems (Duru et al. 2015; Martiniello 2017).

This study identified five main determinants that were associated with farmers' involvement in the process of agroecological innovations development: group membership, access to agricultural credit, access to research & extension institutions, level of education, and perception to participate in the research projects. Group membership had a positive influence on farmers' participation in the development of agricultural innovations since groups were the first channels used by extension workers and agricultural researchers to raise farmers' awareness (Addai et al. 2021). In addition, functional groups were sought after by extension workers and agricultural researchers for field trials (Zossou et al. 2021). A farmers' membership in a group is an incentive for individual and collective learning, which encourages agricultural innovation development and adoption (Leeuwis 2004). It was widely recognized that the development of agroecological practices was often facilitated by farmers' organisations in developing countries (Kilelu et al. 2013).

Farmers' access to agricultural credit was associated with participation in the development and adoption of vegetable innovations. Vegetable farmers with capital were more likely to be involved in the research and development of innovations than those with no money. This result concurs with Hailu et al. (2014), for whom access to agricultural credit reinforced farmers' decision to develop and try out new technologies. According to Gandonou et al. (2019), farmers who benefited from agricultural credit often sought strategies and technical knowledge to make their production more profitable. Indeed, lack of financial resources had negative effects on farmers' decisions towards technology development and adoption (Teno and Lehre 2018).

Access to research and extension institutions has a significant positive effect on farmers' involvement in agroecological innovation development process (Iyabano et al. 2022). According to Etwire et al. (2013), educated farmers were generally the preferred contacts with most agricultural extension agents or researchers. The positive impact of extension and research on agricultural innovation development and adoption has been found by several authors (Yabi et al. 2016; Issoufou et al. 2017). Vegetable farmers benefit from closer contact with research and extension services. They therefore have easy access to information and training on the new technologies (Issoufou et al. 2017). Thus, strengthening and facilitating contacts between vegetable farmers and extension workers or researchers would contribute enormously to vegetable farmers' participation in agroecological innovation development.

Farmers with more formal education were more likely to take part in agroecological development research and extension. This is in line with Caulfield et al. (2022), who showed that households that participated in the participatory research design were the better educated ones. Adebiyi et al. (2019) and Mockshell and Villarino (2019) also found the positive role of education in agroecological technology development and adoption. Thus, policy makers should encourage agroecological education in schools and in local languages with farmers.

Farmers' perception to participate in research projects refers to the views that they hold based on their needs, experiences, and expectations of profitability (Meijer et al. 2015). For example, general interest or disinterest in getting new knowledge were mentioned by rural Andean communities in Peru as main reasons for their participation in the experimental fallow trials (Caulfield et al. 2022). The same authors found that farmers who were practicing agroecological methods were perceived to be more likely to engage in the participatory research projects due to their needs and interest in more sustainable agroecological knowledge. Farmers' perceptions influence whether they participate in individual and/or collective learning (Leeuwis 2004) and consequently in the participatory research. This study revealed that certain farmers might not participate in the agroecological innovation development process unless they receive some gifts or incentives (Leeuwis 2004). This negative perception of some farmers could limit their participation. Agroecological education could be a way to work on mitigating negative perceptions of farmers.

Conclusion

Scaling up agroecological innovations to promote sustainable vegetable farming is needed to achieve sustainable food security and meet environmental challenges. To this end, the paper analysed how agroecological innovation influenced adoption in vegetable farming in Benin. Among agroecological innovations developed by research institutions and other actors over the last ten years and identified in vegetable farming, most were better known in the municipality of Sèmè-Podji, where farmers have more education, greater access to extension services, access to credit, and were more likely to belong to farmers' associations. More local innovations were developed in the municipality of Malanville, where exogenous innovations were less known, so it appears farmers were more motivated to find their own solutions to their needs. Innovations identified and adopted by farmers were related to integrated soil fertility management, integrated pest management and water management (ISFPWM); practices which have been extremely effective in controlling pests and diseases, improving soil fertility, increasing productivity, and achieving sustainable agriculture. Thus, promoting ISFPWM practices would be an effective way to scale-up agroecological farming and achieve sustainable food security and nutrition.

By considering two phases (initiation and implementation) of innovation development, the study showed that many of the farmers were not involved in the initiation phase which involves all activities relating to problem perception, information gathering, attitude formation and evaluation, and resource attainment leading to the decision to adopt the innovation. This phase is essential for innovation development. Educational level, positive attitude about participating in the research projects, access to research and extension institutions, group membership and access to agricultural credit influenced vegetable farmers' involvement in the process of agroecological innovation development. It will be necessary for policy makers and development partners to work on these determinant factors by encouraging agroecological education, facilitating contacts between vegetable farmers and extension workers or researchers, enabling learning by building the capacity of farmers' organisations and improving their access to financial resources. These actions would be a critical way to trigger innovation development and adoption for sustainable agroecological farming systems. Finally, as most vegetable farmers do not have the chance to be involved in the whole process of agroecological research, this study may help policy makers to draw more efficient policies for involving farmers in the process of agroecological innovations.

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References

Abegunde VO, Sibanda M & Obi A 2019, 'The dynamics of climate change adaptation in Sub-Saharan Africa: A review of climate-smart agriculture among small-scale farmers', *Climate,* vol. 7, no. 11, p. 132. https://doi.org/doi:10.3390/cli7110132.

Acemoglu D, Akcigit U & Celik MA 2022, 'Radical and incremental innovation: The roles of firms, managers, and innovators', *American Economic Journal: Macroeconomics*, vol. 14 no. 3, pp. 199-249. https://doi.org/10.1257/mac.20170410.

Achterkamp MC, & Vos JF 2006, 'A framework for making sense of sustainable innovation through stakeholder involvement', *International journal of environmental technology and management,* vol. 6, no. 6, pp. 525-538. https://doi.org/10.1504/IJETM.2006.011895.

AddaiKN, Temoso O, & Ng'ombe JN 2021, 'Participation in farmer organizations and adoption of farming technologies among rice farmers in Ghana' *International Journal of Social Economics*, vol.49 no. 4, pp. 529-545. https://doi.org/10.1108/IJSE-06-2021-0337.

Adebiyi JA, Olabisi LS, Richardson R, Liverpool-Tasie LSO & Delate K 2019, 'Drivers and constraints to the adoption of organic leafy vegetable production in Nigeria: a livelihood approach', *Sustainability*, vol. *12,* no. 1, p. 96. https://doi.org/10.3390/su12010096.

Adolwa IS, Schwarze S, & Buerkert A 2019, 'Impacts of integrated soil fertility management on yield and household income: The case of Tamale (Ghana) and Kakamega (Kenya)', *Ecological Economics*, vol. 161, no.7, pp. 186-192. https://doi.org/10.1016/j.ecolecon.

Akoègninou A, van der Burg WJ, van der Maesen LJG, Adjakidjè V, Essou JP, Sinsin B & Yédomonhan H (eds.) 2006, *Flore analytique du Benin,* pp. 1-1034, Backhuys, Wageningen, Netherlands.

Assogba CG, Vodouhê GT, Adjé B, Dassou A, Tovignan SD, Kindomihou V & Vodouhê SD 2022, 'Agroecological transition in Southern Benin: What challenges for more efficient vegetable farming systems?' *Journal of Agriculture and Rural Development in the Tropics and Subtropics,* vol. 123, no. 2, pp. 205–214. https://doi.org/10.17170/kobra-202210116965.

Beausoleil AM 2018, 'Revisiting Rogers: the diffusion of his innovation development process as a normative framework for innovation managers, students and scholars', *Journal of Innovation Management*, vol. 6 no. 4, pp. 73-97. https://doi.org/10.24840/2183-0606.
Barnes AP, Soto I, Eory V, Beck B, Balafoutis A, Sánchez B & Gómez-Barbero M 2019, 'Exploring the adoption of precision agricultural technologies: A cross regional study of EU farmers', *Land use policy*, vol. *80*, no. 1, pp. 163-174. https://doi.org/10.1016/j.landusepol.
Bhaskaran S 2006, 'Incremental innovation and business performance: small and medium-size food enterprises in a concentrated industry environment', *Journal of Small Business Management*, vol. 44 no. 1, pp. 64-80. https://doi.org/10.1111/j.1540-627X.2006.00154.
Caron P, Ferrero y de Loma-Osorio G, Nabarro D, Hainzelin E, Guillou M, Andersen I & Verburg G 2018, 'Food systems for sustainable development: proposals for a profound four-part transformation', *Agronomy for sustainable development*, vol. 38, pp. 1-12. https://doi.org/10.1007/s13593-018-0519-1
Caulfield ME., Vanek SJ, Meza K, Huaraca J, Loayza JL, Palomino S, Olivera E, Ccanto R, Scurrah M, Vigil L & Fonte SJ 2022, 'Drivers of farmer involvement in experimental forage trials in the Peruvian Andes and implications for participatory research design' *Experimental Agriculture*, vol. *58*, p. e39. https://doi:10.1017/S0014479722000357.
Chaudhary A, Timsina P, Karki E, Sharma A, Suri B, Sharma R & Brown B 2023, 'Contextual realities and poverty traps: Why South Asian smallholder farmers negatively evaluate conservation agriculture' Renewable Agriculture and Food Systems, 38, e13. https://doi.org/10.1017/S1742170523000066.
Côte FX, Poirier-Magona E, Perret S, Rapidel B, Roudier P & Thirion MC 2019, *The agroecological transition of agricultural systems in the Global South,* Agricultures et défis du monde collection, AFD, CIRAD, Éditions Quæ, Versailles, France.
Damanpour F 1991, 'Organizational innovation: a meta-analysis of effects of determinants and moderators' *Academic Management Journal*, vol. 34, no 3, pp. 555-590. http://www.jstor.org/stable/256406.
David S & Asamoah C 2011, 'The impact of farmer field schools on human and social capital: A case study from Ghana', *The Journal of Agricultural Education and Extension*, vol. 17 no. 3, pp. 239-252. https://doi.org/10.1080/1389224X.2011.559076.
D'Annolfo R, Gemmill-Herren B, Amudavi D, Shiraku HW, Piva M & Garibaldi LA 2021, 'The effects of agroecological farming systems on smallholder livelihoods: A case study on push–pull system from Western Kenya', *International Journal of Agricultural Sustainability*, vol. 19, no. 1, pp. 56-70. https://doi.org/10.1080/14735903.2020.1822639.
Dean A & Schultz T 2023, 'From theory to practice-how insights from psychology can be applied in agricultural extension', *Rural Extension and Innovation Systems Journal*, vol. *19, no.* 1, pp. 22-33. http://www.apen.org.au/rural-extension-and-innovation-systems-journal.
Duru M, Therond O & Fares MH 2015, 'Designing agroecological transitions: A review', *Agronomy for Sustainable Development*, vol. *35*, pp. 1237-1257. https://doi.org/10.1007/s13593-015-0318-x.
El Bilali H 2019, 'Innovation-sustainability nexus in agriculture transition: Case of agroecology', *Open Agriculture*, vol. 4, no. 1, pp. 1-16. https://doi.org/10.1515/opag-2019-0001.
Etwire PM, Dogbe W, Wiredu AN, Martey E, Etwire E, Owusu R K & Wahaga E. 2013, 'Factors influencing farmer's participation in agricultural projects: the case of the agricultural value chain mentorship project in the Northern region of Ghana', *Journal of Economics and Sustainable Development,* vol. 4, no. 10, pp. 1-9 https://doi.org/10.7176/JESD.
El-Sheikh ESA, Ramadan MM, El-Sobki AE, Shalaby AA, McCoy MR, Hamed IA, Ashour MB & Hammock BD 2022, 'Pesticide Residues in Vegetables and Fruits from Farmer Markets and Associated Dietary Risks', *Molecules*, vol. 27, p. 8072. https://doi.org/10.3390/molecules27228072.
FAO 2018a, *The future of food and agriculture: alternative pathways to 2050,* Food and Agriculture Organization (FAO) of the United Nations. Rome, Italy, 2018.
FAO 2018b, *The 10 elements of agroecology: guiding the transition to sustainable food and agricultural systems*, Food and Agriculture Organization (FAO) of the United Nations, Rome, Italy, 2018 - 9037EN/1/04.18.
Faure G, Chiffoleau Y, Goulet F, Temple L & Touzard JM 2018, *Innovation and development in agricultural and food systems*, Editions Quæ, Versailles Cedex France.
Gandonou E, Chogou SK & Adegbidi A 2019, 'Impact du conseil agricole privé sur l'efficacité technique des petits producteurs d'ananas au Bénin', *Économie rurale*, vol. 368, no 2, pp. 55-73. https://doi.org/10.4000/economierurale.6736.
Greenbaum TL 2000, *Moderating focus groups: A practical guide for group facilitation*; Thousand Oaks, CA: Sage Publications. https://doi.org/10.4135/9781483328522.
Issoufou OH, Boubacar S, Adam T & Yamba B 2017, 'Determinants de l'adoption et impact des variétés améliorées sur la productivité du mil au Niger', *African Crop Science Journal*, vol. *25, no* 2, pp. 207-220. http://dx.doi.org/10.4314/acsj.v25i2.6.
Iyabano A, Klerkx L, Faure G & Toillier A 2022, 'Farmers' Organizations as innovation intermediaries for agroecological innovations in Burkina Faso', *International Journal of Agricultural Sustainability*, vol. 20, no 5, pp. 857-873. https://doi.org/10.1080/14735903.2021.2002089.
Kilelu CW, Klerkx L & Leeuwis C 2013, 'Unravelling the role of innovation platforms in supporting co-evolution of innovation: Contributions and tensions in a smallholder dairy development programme', *Agricultural systems*, vol. *118*, pp. 65-77. https://doi.org/10.1016/j.agsy.2013.03.003.
Kolb DA 1984, *Experiential learning: Experience as the source of learning and development*, Englewood Cliffs', Prentice-Hall, NJ, USA.
Leeuwis C 2004, *Communication for rural innovation: rethinking agricultural extension*, 3rd edn, Blackwell, United of Kingdom.

Leeuwis C & Aarts N 2011, 'Rethinking communication in innovation processes: creating space for change in complex systems', *Journal of agricultural education and extension*, vol. *17, no* 1, pp. 21-36. https://doi.org/10.1080/1389224X.2011.536344.

Loconto AM, Poisot AS & Santacoloma P 2017, 'Sustainable Practices, Sustainable Markets? Institutional innovations in agri-food systems*',* in *AgroEcological Transitions. Changes and Breakthroughs in the Making* eds. B Elzen , A Augustyn , M Barbier & B van Mierlo, Wageningen University & Research, Netherlands, pp. 176-191.

MAEP 2017, *Plan Stratégique de Développement du Secteur Agricole (PSDSA) 2025 et Plan National d'Investissements Agricoles et de Sécurité Alimentaire et Nutritionnelle (PNIASAN) 2017- 2021*. Ministère de l'Agriculture, de l'Elevage et de la Pêche (MAEP) du Bénin.

Martiniello G 2017, 'Agrarian politics and land struggles in Northern Uganda', *Community Development Journal*, vol. 52, no 3, pp. 405-420. https://doi.org/10.1093/cdj/bsx027.

Meadow AM, Ferguson DB, Guido Z, Horangic A, Owen G & Wall T 2015, 'Moving toward the deliberate coproduction of climate science knowledge', *Weather, Climate, and Society*, vol. *7, no* 2, pp. 179-191.http://dx.doi.org/10.1175/WCAS-D-14-00050.1.

Meijer SS, Catacutan D, Ajayi OC, Sileshi GW & Nieuwenhuis M 2015, 'The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa', *International journal of agricultural sustainability*, vol. 13, no. 1, pp. 40-54. https://doi.org/10.1080/14735903.2014.912493.

Mockshell J & Villarino MEJ 2019, 'Agroecological intensification: Potential and limitations to achieving food security and sustainability', in *Encyclopedia of food security and sustainability, Elsevier , Amsterdam, Netherlands ,* https://doi.org/10.1016/B978-0-08-100596-5. 22211-7.

Musiolik J, Markard J & Hekkert M 2012, 'Networks and network resources in technological innovation systems: Towards a conceptual framework for system building', *Technological Forecasting and Social Change*, vol. 79, no 6, pp. 1032-1048. https://doi.org/10.1016/j.techfore.2012.01.003.

Ndegwa JK, Gichimu BM, Mugwe JN, Mucheru-Muna M & Njiru DM 2023, 'Integrated Soil Fertility and Water Management Practices for Enhanced Agricultural Productivity', *International Journal of Agronomy*, *vol. 2023 pp. 1-8*. https://doi.org/10.1155/2023/8890794.

Nordey T, Basset-Mens C, De Bon H, Martin T, Déletré E, Simon S, Parrot L, Despretz H, Huat J, Biard Y, Dubois T & Malézieux E 2017, 'Protected cultivation of vegetable crops in sub-Saharan Africa: limits and prospects for smallholders. A review', *Agronomy for Sustainable Development* vol. 37, no. 53, pp. 1-20. https://doi.org/10.1007/s13593-017-0460-8.

OECD 2021, *Knowledge co-creation in the 21st century a cross-country experience based policy report,* OECD Science, Technology and Industry Working Papers, June 2021 no. 115

Okonta OW, Ajala AO, Kolawole EA, Ogunjimi SI, Adejumo AA 2023, 'Willingness to Adopt Organic Farming Practices among Arable Crop Farmers in Oyo State, Nigeria', *Journal of Agricultural Extension* vol. 27, no. 3, pp. 41- 52. https://dx.doi.org/10.4314/jae.v27i3.5.

Olutumise AI 2023, 'Impact of credit on the climate adaptation utilization among food crop farmers in Southwest, Nigeria: application of endogenous treatment Poisson regression model', *Agricultural and Food Economics*, vol. 11, no. 1, pp. 1-19. https://doi.org/10.1186/s40100-023-00251-0.

Osabohien R, Matthew O, Gershon O, Ogunbiyi T & Nwosu E 2023, 'Agriculture Development, Employment Generation and Poverty Reduction in West Africa' *The Open Agriculture Journal*, vol. 13, no. 83, pp. 82-89, https://doi.org/10.2174/1874331501913010082.

Paez A 2017, 'Gray literature: An important resource in systematic reviews', *Journal of Evidence-Based Medicine*, vol. 10, no. 3, pp. 233-240. https://doi.org/10.1111/jebm.12265.

PDC Malanville 2017, *Plan de Développement Communal (PDC) de Malanville 2017-2021*. Commune de Malanville, Bénin, Rapport, p. 217.

Rehman A, Farooq M, Lee DJ & Siddique KH 2022, 'Sustainable agricultural practices for food security and ecosystem services', *Environmental Science and Pollution Research*, vol. 29, no. 56, pp. 84076 -84095. https://doi.org/10.1007/s11356-022-23635-z.

Rogers EM 1983, *Diffusion of innovations*, 3rd edn, Free Press, New York

Rogers EM 1995, *Diffusion of innovations,* 5th edn, Free Press, New York.

Sanjek R 2000, 'Keeping ethnography alive in an urbanizing world', *Human organization*, vol. 59, no.3, pp. 80-288. https://doi.org/10.17730/humo.59.3.5473111j42374034.

Staw BM 1990, 'An evolutionary approach to creativity and innovation*',* in *Innovation and creativity at work: Psychological and organizational strategies, eds. MA West & JL Farr, England, United Kingdom, pp. 287-308.*

Souleymane LY, Sarr I, Martinez RT & Ndiaye S 2021, 'Caractérisation des Pratiques de Traitements Phytosanitaires dans la Zone de Culture Maraichère des Niayes du Sénégal', *International Journal of Progressive Sciences and Technologies*, vol. 30, no. 1, pp. 301–313. https://ijpsat.org/index.php/ijpsat/article/view/3878

Tekeste K, Degefa T, Admasu S, Dawit A 2023, 'Determinants of adoption of improved varieties of Wheat (*Triticum aestivum*), Teff (*Eragrostis teff*), and Maize (*Zea mays L.*) in Central Ethiopia', *Journal of Agricultural Extension vol. 27, no.* 2, pp. 1-14. https://dx.doi.org/10.4314/jae.v27i2.1.

Teno G, Lehrer K & Koné A 2018, 'Les facteurs de l'adoption des nouvelles technologies en agriculture en Afrique Subsaharienne: une revue de la littérature', *African Journal of Agricultural and Resource Economics*, vol. 13, pp. 140-151. https://doi.org/10.22004/ag.econ.274735.

Tittonell P, Piñeiro G, Garibaldi LA, Dogliotti S, Olff H & Jobbagy EG 2020, 'Agroecology in large scale farming: A research agenda', *Frontiers in Sustainable Food Systems,* vol. 4, pp. 584-605. https://doi.org/doi:10.3389/fsufs.2020.584605.

Trinh ST, Hoang HG & Drysdale D 2023, 'Extension workers' perception of information and communication technology utilisation for extension services in Vietnam', *Rural Extension and Innovation Systems Journal*, vol. 19, no. 2, pp. 1-8. http://www.apen.org.au/rural-extension-and-innovation-systems-journal

Utter A, White A, Méndez VE & Morris K 2021, 'Co-creation of knowledge in agroecology', *Elementa: Science of the Anthropocene* , vol. 9, no. 1, pp.1-16. https://doi.org/10.1525/elementa.2021.00026.

Van der Veen M 2010, 'Agricultural innovation: invention and adoption or change and adaptation?', *World Archaeology*, vol. 42, no. 1, pp. 1-12. https://doi.org/10.1080/00438240903429649.

Weyori AE, Amare M, Garming H & Waibel H 2018, 'Agricultural innovation systems and farm technology adoption: findings from a study of the Ghanaian plantain sector', *The Journal of Agricultural Education and Extension*, vol. 24, no. 1, pp. 65-87. https://doi.org/10.1080/1389224X.2017.1386115.

Wijeratne M & De Silva WN 2023, 'The paradigm shift of agricultural extension from technology transfer towards participatory approaches', *The Journal of Agricultural Sciences - Sri Lanka,* vol. *19, no.* 1, pp. 1-13. https://doi.org/10.4038/jas.v19i1.9851.

Williamson S, Ball A & Pretty J 2008, 'Trends in pesticide use and drivers for safer pest management in four African countries', *Crop Protection*, vol. 27, no. 10, pp. 1327-1334. https://doi.org/10.1016/j.cropro.2008.04.006

Yabi JA, Bachabi FX, Labiyi IA, Ode CA & Ayena RL 2016, 'Déterminants socio-économiques de l'adoption des pratiques culturales de gestion de la fertilité des sols utilisées dans la commune de Ouaké au Nord-Ouest du Bénin', *International Journal of Biological and Chemical Sciences*, vol. *10, no.* 2, pp. 779-792. http://dx.doi.org/10.4314/ijbcs.v10i2.27.

Yarou BB, Silvie P, Assogba Komlan F, Mensah A, Alabi T, Verheggen F & Francis F 2017, 'Plantes pesticides et protection des cultures maraichères en Afrique de l'Ouest (synthèse bibliographique)' *Biotechnologie, Agronomie, Société et Environnement*, vol. 21, no. 4, pp. 288-304. https://doi.org/10.25518/1780-4507.20670.

Yegbemey RN, Komlan Anihou CM, Olorunnipa I, Benali M, Afari-Sefa V & Schreinemachers, P 2021, 'COVID-19 effects and resilience of vegetable farmers in north-western Nigeria', *Agronomy*, vol. 11, no. 9, pp.1-16. https://doi.org/10.3390/agronomy11091808.

Zhang H, Mao R, Huang H, Dai Q, Zhou X, Shen H & Rong G 2021, 'Processes, challenges and recommendations of Gray Literature Review: An experience report', *Information and Software Technology*, vol. *137*, p 106607. https://doi.org/10.1016/j.infsof.2021.106607.

Zossou E, Zoundji GC, Aplogan A & Vodouhe SD 2021, 'La participation des producteurs au conseil agricole: Determinants et leçons apprises dans le département de l'Atlantique au Benin'. *Agronomie Africaine*, vol. 33, no. 1, pp. 95-105.

Zossou E, Arouna A, Diagne A & Agboh-Noameshie RA 2020, 'Learning agriculture in rural areas: the drivers of knowledge acquisition and farming practices by rice farmers in West Africa', *The Journal of Agricultural Education and Extension*, vol. *26, no.* 3, pp. 291-306. https://doi.org/10.1080/1389224X.2019.1702066

Zoundji GC, Okry F, Vodouhê SD, Bentley JW & Witteveen L 2020, 'Commercial channels vs free distribution and screening of agricultural learning videos: A case study from Benin and Mali' *Experimental Agriculture*, vol. *56, no.* 4, pp. 544-560. https://doi.org/10.1017/S0014479720000149.

Zoundji GC, Okry F, Vodouhê SD & Bentley JW 2016, 'The distribution of farmer learning videos: Lessons from non-conventional dissemination networks in Benin', *Cogent Food & Agriculture*, vol. *2, no.* 1, p. 1277838. https://doi.org/10.1080/23311932.2016.1277838.

Zoundji CG, Okry F, Vodouhê DS & Bentley JW 2018, 'Towards sustainable vegetable growing with farmer learning videos in Benin', *International Journal of Agricultural Sustainability,* vol. 16, no. 1, pp. 54-63, https://doi.org/10.1080/14735903.2018.1428393