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Exploring factors that shape small-scale farmers' opinions on the adoption of eco-friendly nets for vegetable production

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Abstract If agro-ecological systems are to realize their potential as sustainable alternatives to conventional agricultural systems, innovation diffusion needs to be enhanced. We conducted surveys among 214 small-scale vegetable farmers in Benin, a food-deficit country in West Africa, on how they perceived the different attributes of eco-friendly nets (EFNs). The nets act as physical barriers against insects in vegetable production and so reduce pesticide use. Understanding farmer perceptions about new technologies helps reveal farmers' propensity to adopt them. Intensity of attitude was measured on a Likert scale, and an ordered probit model was used to determine which characteristics of nets were most influential. Eighteen percent of farmers thought that EFNs would benefit them, but almost half preferred not to adopt this technology at all. The main reason for rejecting the nets was the perceived high labor requirement, particularly on larger plots of land. This largely negative perception was strongest among farmers with large areas cultivated with vegetables, farmers who had little or no experience in a trial, and those living far from extension services. We recommend expanded trials that engage a higher proportion of farmers, strengthening of external support for those wanting to use the nets and further technological development to reduce labor costs, improved access to finance and increased education about the negative impacts of insecticides abuse.

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1 Introduction

The agricultural sector faces major challenges if it is to meet global demand (Tilman et al. 2011; Campbell et al. 2014). New agricultural pathways to growth are essential if agricultural productivity is to increase in the face of rises in the price of fossil fuels, the impact of synthetic pesticides on human health and soil erosion (Garnett et al. 2013; FAO 2014; Vermeulen 2014). One solution to these challenges is the implementation of innovations that can optimize agricultural production while at the same time reducing the pressure on natural resources (Zhang et al. 2007; Birch et al. 2011). In many countries, this process is encompassed by the term 'agro-ecology'—as a movement, a science, and a practice (Altieri 2002; Wezel et al. 2009). Following Chambers work (Chambers and Ghildyal 1985; Chambers 1997), the concept of agro-ecology also puts the farmer at the core of the process and is a way to allow them to retain their livelihoods in the face of expanding agribusiness that would otherwise displace them (Altieri 2002; Wiggins et al. 2010).

One of the major applications of agro-ecological systems, particularly in developing countries, has been technologies that reduce the use of synthetic pesticides, such as integrated pest management (IPM) practices. In tropical areas, the lack of cold seasons and the presence of vegetation year round make fruit and vegetables highly vulnerable to pest infestations. Farmers manage the high risk of significant yield reduction or even crop loss by using pesticides in large quantities (Martin et al. 2006; Ahouangninou et al. 2011, 2012; Waterfield and Zilberman 2012; de Bon et al. 2014). In many parts of the tropical world, including Africa, vegetable production is highly dependent on insecticides, not only in

Fig. 1 Eco-friendly net use in Benin: cabbage plots covered with the net (*left*); net being set up over a cabbage plot (*right*)

places dominated by large-scale cash crops but also in small-holder production systems (Lund et al. 2010; Probst et al. 2012a, b). However, inappropriate application of pesticides can contaminate the environment (Pimentel 1995, 2005) and impinge on the health of both those applying the pesticides and the consumers buying the produce (Williamson 2005; Ntow et al. 2006; Ahouangninou et al. 2012).

One innovative approach to reduce the use of pesticides by vegetable growers is to exclude a high proportion of the insect pests with nets, termed 'eco-friendly nets' (EFNs). EFNs can reduce pesticide use by at least 70 %, sometimes by even 100 % (Martin et al. 2006; Licciardi et al. 2008; Simon et al. 2014), hence the term 'eco-friendly.' EFNs have proved to be a viable alternative to harmful and unsustainable insecticide application practices in France (Sauphanor et al. 2012), Kenya (Gogo et al. 2014) and Benin (Martin et al. 2006; Licciardi et al. 2008; Simon et al. 2014).

The EFNs are cut to cover an iron or wooden frame over a small plot (commonly 12 m^2 in Southern Benin; Fig. 1). While sometimes provided as part of aid interventions, the nets were shown to be profitable in Benin even when purchased at full market price, when full labor costs are included or should yield be reduced by low levels of pest infestation (Vidogbéna et al. 2015b).

EFNs are generally made of recyclable polyethylene (AgroNet®, A to Z Textile Mills, Tanzania), but bio-based renewable netting from starch has been recently developed (FILBIO® PLA, Texinov, France). The mesh size recommended depends on climate and the size of the pests to be excluded. In tropical Benin, both fine mesh nets (0.4 mm) and larger mesh (0.9 mm) are used to protect cabbage from major lepidopteran pests (*Plutella xylostella*, *Hellula undalis*, *Helicoverpa armigera*, and *Spodoptera littoralis*) and aphids (*Lipaphis erysimi*). Nets ought to be removed during daylight hours, when pests specializing in cabbage are inactive (Fig. 1), to enable regulation of aphids populations by their natural enemies (predators and parasitoids) and to prevent overheating and excessive shade (Martin et al. 2006; Licciardi et al. 2008; Muleke et al. 2014; Simon et al. 2014). While net should be removed every day, most farmers prefer to remove them just three times a week to reduce labor costs (Simon et al. 2014).

The aims of this paper are to assess cabbage farmers' opinions about the use of EFNs as an alternative to the exclusive use of synthetic pesticides in Benin and to analyze factors influencing their opinions and their acceptance of the nets. In Benin, insects cause an average yield loss of 30–40 % (Matthews 2008).

On the assumption of utility maximization, Benin farmers might be expected to choose to adopt the technology that yields the highest expected profits. However, this choice will be adjusted for risk (Feder et al. 1985), and farmers are often cautious of adopting new technologies, especially where the use of a new technology is closely linked to food security. Therefore, understanding perceptions of innovative technology by potential users early is crucial to adoption (Negatu and Parikh 1999; Ormsby and Kaplin 2005; Allendorf et al. 2006; Ramakrishnan 2007; Vodouhê et al. 2010). Perceptions depend on the information available about a new technology and prior expectations (Feder et al. 1985; Saha et al. 1994; Saltiel et al. 1994; Dimara and Skuras 2003; Marra et al. 2003; Diagne and Demont 2007; Kabunga et al. 2012).

The paper contributes to the growing body of literature incorporating farmers' perceptions and knowledge into the development and adoption of IPM practices in Africa (Van Huis and Meerman 1997; Orr and Ritchie 2004; Obopile et al. 2008).

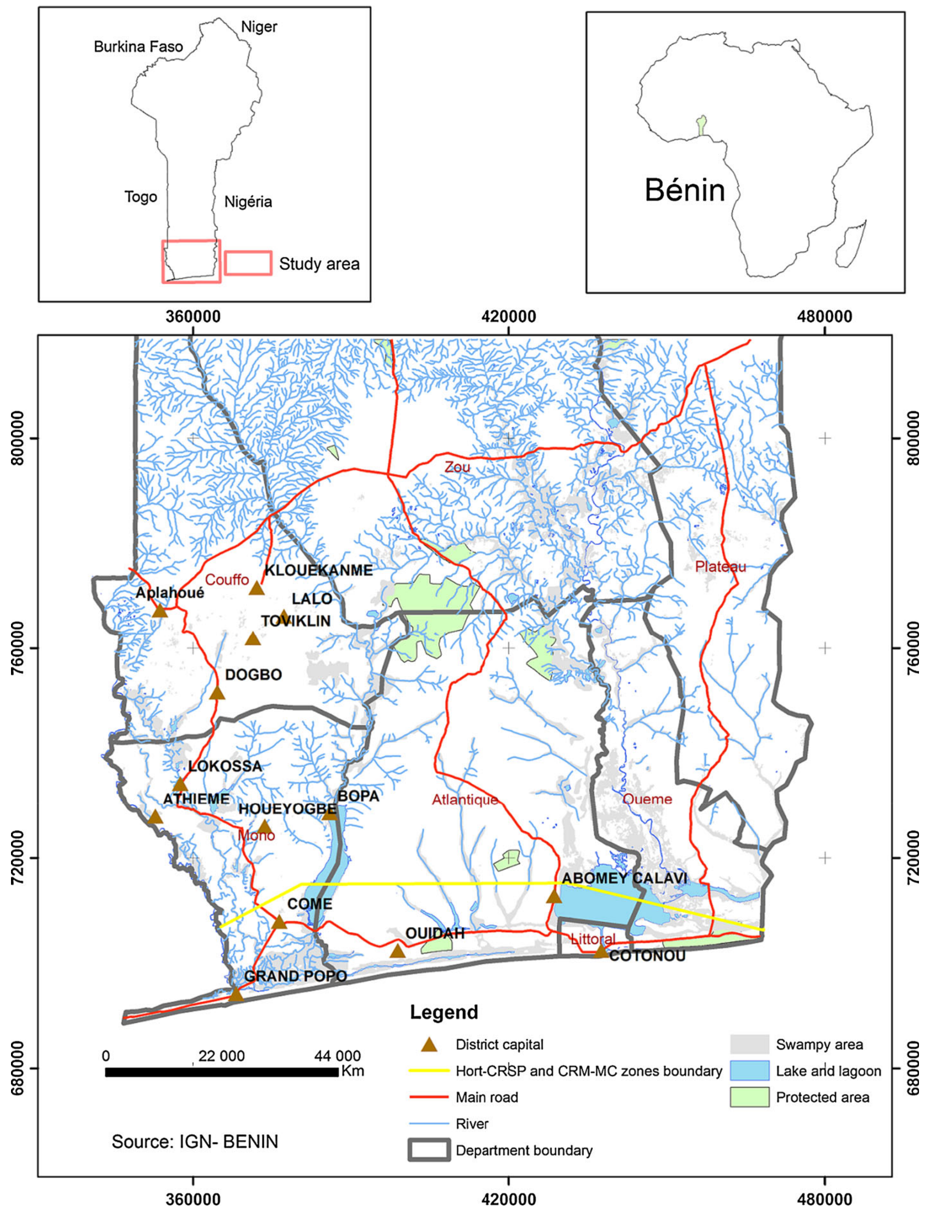

Fig. 2 Research area in southern Benin, divided into a coastal and an inland zone (*horizontal line*). Study townships are indicated by *brown triangles*. The *yellow lines* divide the coastal zone in the south from the inland zone in the north. *Note Hort-CRSP* Horticulture Collaborative Research Support Program, *CRM-MC* Conseil Régional des Maraîchers du Mono et du Couffo (Regional Council of vegetable growers of Mono and Couffo departments)

2 Materials and methods

2.1 Framework

An innovation is an idea, a practice, or an object perceived as new by a person or a decision unit (Rogers 2003). Agro-ecological innovations are embedded in a broader socioecological context, and the innovation adoption tends to be a process of co-learning and adaptation between the user and the provider of the innovation. It can thus be expected that perceptions about an innovation are context specific and require specific methodologies to estimate them.

Adoption here is defined as the process that occurs between the time an individual first hears about an innovation to using it in full knowledge of its advantages, limitations, and potential (Feder et al. 1985). The process includes five steps: awareness, persuasion, decision, implementation, and confirmation (Rogers 2003). We distinguish between a pre-decision and post-decision phase. When a technology is about to be introduced or has recently been introduced, most studies focus on the pre-decision phase, particularly on persuasion where attitudes toward a technology's characteristics, risks, benefits, and uncertainties determine the adoption decision (Alcouffe 2004). Our study is guided by Venkatesh's model (2003) which shows that three latent variables influence individual intention to use an innovative technology. The first is 'anticipated performance' signifying the degree to which an individual believes that using a technology will improve their livelihood. The second is 'ease of use' which is a measure of the amount of effort required to use the technology. The third, 'social pressure,' is defined as the degree to which an individual is influenced by what other people believe they should adopt. A fourth latent variable, 'external support,' the degree to which an individual believes that an organizational and technical infrastructure exists to support the adoption of the technology, can also determine a decision about using a new technology (Venkatesh et al. 2003; Tibenderana and Ogao 2008; Kysanayotin et al. 2009).

2.2 The research area

The study was carried out in two geographical zones, one coastal (townships indicated by the red triangles under the yellow line in Fig. 2) and the other inland (townships indicated by the red triangles beyond the yellow line in Fig. 2). Farming households in the coastal zone are spread along the Benin offshore sand bar across six townships in four departments[1]: Sèmè-Podji (Department Ouémé), Cotonou (Department Littoral), Abomey-Calavi and Ouidah (Department Atlantique), and Comé and Grand-Popo (Department Mono). The Inland Zone comprises nine townships across two departments: Bopa, Houéyogbé, Lokossa, and Athiémé (Department Mono), Dogbo, Aplahoué, Toviklin, Klouékanmè, and Lalo (Department Couffo).

All respondents practice urban and peri-urban farming. However, local production does not meet domestic demand across all of Benin, and so significant quantities of exotic vegetables are imported (Tokanou and Quenum 2007; Probst et al. 2012a). Farmers in the coastal zone grow exotic vegetables such as cabbage (*Brassica oleracea*), eggplant (*Solanum melongena*), tomato (*Solanum lycopersicon*), lettuce (*Lactuca sativa*), watermelon (*Citrullus lanatus*), cucumber (*Cucumis sativus*), and carrots (*Daucus carota*). Some

[1] A department in Benin is the first subdivision of the country. The country is subdivided into 12 departments and each department is subdivided in 5–9 communes.

local vegetables—African eggplant (*Solanum macrocarpum*), pepper (*Capsicum frutescens)*, amaranth (*Amaranthus caudatus*) and basil (*Ocimum gratissimum* and *Ocimum basilicum*)—are also grown. Both exotic and local vegetables are grown on small plots using an intensive production system. The main limitation for farmers in the coastal zone is the lack of land for agriculture, insecure land tenure, and the relatively high population density. Therefore, the problem of using more and more synthetic pesticides to boost productivity on limited land is more serious in the coastal than in the inland Zone.

Farmers in the inland zone have access to more land and practice low-input production systems. They also produce a range of exotic vegetables (tomato, lettuce, and cabbage) as well as local ones such as African eggplant, pepper, and amaranth. The main limitation to farmers in the inland zone is the poor access to markets due to poor road conditions and high transport costs. Most of the cultivated vegetables in both areas are sold at farm gate by traders supplying main or secondary markets in Cotonou and Abomey-Calavi. Surplus vegetables are sold, mostly by women, at local markets within the community. Farmers in the coastal zone have access to better road infrastructures and lower costs to access markets, extensions services, and suppliers for pesticides among others.

2.3 Sampling

All farmers in the sample frame had been involved in a series of demonstration trials of EFNs, either as owner of the trial site or as observer. In total, 90 farmers were randomly approached on whose farms the trials were carried out. Each of these 90 farmers formed a network with five other randomly chosen farmers. These randomly chosen farmers, referred to as observers, were invited to watch the EFNs trials on the owners' farms. Therefore, the sample frame consisted of 540 (90 owners + 450 observers) farmers in total, grouped into 90 networks of six. The reason we sampled only from these farmers is that, in order to adopt a new technology, farmers need to have at least some knowledge of and exposure to it (e.g., Saha et al. 1994; Dimara and Skuras 2003; Diagne and Demont 2007; Kabunga et al. 2012). When approaching the owners, no potential benefits were mentioned and no incentives were offered. However, these farmers were informed that o additional costs occurred to them by allowing the trials to be carried out on their farms, i.e., the required inputs for the trials were provided (Table 1).

Table 1 Number of farmers involved in EFNs trials implementation and number of those interviewed

Zone	Farmers on whose farms trials were undertaken (owners)	Farmers who have observed trial implementation of EFNs at least once (observers)	Owners interviewed (a)	Observers interviewed (b)	Total interviewed (a + b)
Coastal	48	245	48	66	114
Inland	42	220	42	58	100
Total	90	465	90	124	214

While we wanted to interview all of the selected 90 owners, we could only sample a fraction of the 450 observers. We determined the required sample size for the observers by applying the Moivre–Laplace theorem as suggested by Advantages surveys (Advantages 2004) for large samples ($n > 30$). The sample size (n) is obtained by:

$$n = \mu_{\alpha}^{2} \frac{F_n(1 - F_n)}{\delta^2} \quad (1)$$

where μ_{α} is the 'p value' of the standard normal distribution ($\mu_{\alpha} = 1.96$), F_n is the proportion of vegetable growers who took part in the demonstration trials, and δ is the half-amplitude of the confidence interval, equal to the selected confidence level of 0.05. Integration of these data in Eq. (1) showed that the required sample size was 214. This meant that we needed to randomly select 124 observers additionally to the 90 owners. We finally interviewed 124 observers, 66 from the coastal zone and 58 from the inland zone.

2.4 Data collection and questionnaire

All farmers, owners, and observers were approached by staff from two private institutions: APRETECTRA,[2] a NGO, in the coastal zone and CRM-MC,[3] a farmer association, in the inland zone. These were responsible for the distributions of the EFNs and training to use the EFNs trial protocol designed by INRA (Institut National des Recherches Agricoles du Bénin), the national coordinator of the net distributions. Both APRETECTRA and CRM-MC were selected as collaborators for the project 'Low cost pest exclusion and micro-climate modification technologies for small-scale vegetable growers in East and West Africa,' funded by USAID with the aim to promote and diffuse the use of EFNs for the improvement of rural people's livelihoods. Both institutions further provide technical advice and financial support to vegetable farmers in Mono and Couffo departments.

The main survey was carried out in March 2012 over 4 weeks. Before this, we conducted a pilot survey at the beginning of 2012 to gather information for the questionnaire design. Local co-researchers were trained to help with data collection. One interview took, on average, nearly an hour. We used structured questionnaires which included questions on demography and livelihood and farm production and a series of Likert scale-type questions (Likert 1932) to assess farmers' perceptions toward the use of EFNs. These scales had five points, ranged from 1 to 5: 5 = strongly agree, 4 = agree, 3 = indifferent, 2 = weakly agree, and 1 = strongly disagree. Based on the innovation diffusion framework (Rogers 2003), we assessed farmers' scores against four attributes: performance, ease of use, social pressure, and external support (Table 2), all attributes that influence farmers' acceptance and use of innovations (Venkatesh et al. 2003).

2.5 Data processing and analysis

Descriptive statistics of the sample were obtained using the SPSS (Statistical Package for the Social Sciences), version 16. Homogeneity in the ranking was investigated using the Kendall (W) concordance coefficient (Légendre 2005) $W(\in[0, 1])$ which is a measure of the

[2] Association des Personnes Rénovatrices des Technologies Traditionnelles—Association of people reforming traditional technologies.

[3] Conseil Régional des Maraîchers du Mono et du Couffo—Regional Council of vegetable farmers of Mono and Couffo departments.

Table 2 Farmers perceived items related to EFN attributes and their meaning

Innovation attribute	Attributes of EFNs according to farmers	Criteria related to farmers' expectations about using EFNs
Performance degree to which an individual believes that a new technology will help to increase output and efficiency	1.1 Utility 1.2 Targeted insects 1.3 Labor costs 1.4 Time savings 1.5 Vegetable quality 1.6 Health expenditure 1.7 Efficiency 1.8 Life conditions	1.1 EFNs can be a barrier for all insects 1.2 EFNs can be an effective barrier for certain targeted pests 1.3 EFNs can increase or decrease the number of workers hired 1.4 EFNs can save working time 1.5 EFNs can improve the physical quality of cabbages 1.6 EFNs can eradicate or at least reduce diseases related to insecticide spray 1.7 EFNs are cheaper to use than the current practice 1.8 EFNs can improve the livelihoods of cabbage producers
Ease of use degree of knowledge required to understand the principles and uses of a new technology, as well as of the information provided by researchers and agents to users	2.1 Complex to learn 2.2 Complex to use 2.3 Complex to transfer	2.1 EFNs are easy to adopt 2.2 The use of EFNs is easy to understand 2.3 EFNs know-how can easily be transferred to others
Social pressure the social environment of farmers, which may impact on their perceptions and adoption behaviors	3.1 Relevant persons' influence 3.2 Distributors' influence 3.3 Community influence	3.1 EFNs could be recommended to others by relevant persons from their social environment 3.2 Use of EFNs depends heavily on the relationship with the distributors 3.3 EFNs could receive communal consent
External support degree to which an individual believes that appropriate organizational and technical infrastructure exists to support a new technology	4.1 Self-funding skills 4.2 Level of personal knowledge 4.3 Barriers to use 4.4 Accessibility to technical support 4.5 Accessibility to financial support	4.1 EFNs should be paid for by the farmers 4.2 EFNs could be supported by farmers' skills and knowledge 4.3 EFNs can be used by anybody without barriers and nobody should be excluded 4.4 EFNs should be facilitated by easy access to technical support 4.5 EFNs should be facilitated by easy access to financial support (subsidies, gifts, credits for example)

Table 3 Determination of the overall perception index indicating farmers' opinions about key attributes of EFNs (adapted from Rahman 2003)

Degree of agreement/ disagreement of the item	0		1	2	
Likert point (Rm)	1	2	3	4	5
Level of agreement	Very low	Low	Middle	High	Very high
Weigh (Pq)	0.2	0.4	0.6	0.8	1
Aggregated perception index of the ith respondent (APeI)	$IP_i = \sum_{j=1}^{19} \sum_{m=1}^{5} \sum_{q=0,2}^{1} VRP_{jmq} \quad \forall j = 1, 2, \ldots, 19; \quad m = 1, \ldots, 5 \text{ and } \quad q = 0; 0, 2, \ldots 1$				
Aggregated perception index for the sample (GPI)	$\frac{IP_i}{N}$ where N = total number of items				

0 = farmers expect higher utility from current practice than from EFNs, 1 = farmers expect the same utility from EFNs and current practice, 2 = farmers expect higher utility from EFNs than from current practice

agreement among more than one (p) survey respondents who are assessing a given set of (n) objects. The closer the W is to 1, the greater the unanimity in the opinion of farmer about the importance of the targeted attribute.

We assumed that each attribute of the technology to be adopted (here the EFNs) can be weighted by the farmers according to their expectations. This overall perception index was based on the aggregation of the Likert scale scores (Table 3). The aggregated weight of farmers' perceptions of key attributes of the nets was used as an indicator of farmers attitude toward its adoption (Ormsby and Kaplin 2005; Allendorf et al. 2006; Ramakrishnan 2007; Vodouhê et al. 2010).

We assumed that an overall perception index of at least 0.70 indicated that the nets were preferred over current practices using only pesticides. For an overall perception index (OPI) between 0.60 and 0.69, we assumed that the two technologies would provide the same satisfaction to the farmers.

The perception index was regressed on various socioeconomic variables by using an ordered probit model. Factors explaining heterogeneity among farmers' perceptions were estimated by a probabilistic model in STATA version 10.0. Farmers' perceptions about the use of EFNs were estimated using an ordered probit model as the perception indices were coded as ordered values. In order to compare perceptions about EFNs with those for current methods, an ordered probit model was preferred over a multinomial logit or probit model as these would fail to have accounted for the ordinal nature of the dependent variable (Greene 2002).

The econometrical model used was as follows:

$$\forall k \in (1, 2, 3), \quad y_i = k \Leftrightarrow S_k < y_i^* = X_i\beta + \mu_i \leq S_{k+1} \tag{2}$$

where Y_i^* is the dependent variable—the preference of a farmer. The preference is given by the difference between the marginal net benefits of one of the two technologies against the other. Y_i represents the three categories with the values:

- 0 = EFN is expected to have lower utility (benefit) than the current practice of pesticide use. This means that farmers are likely to reject the use of EFN.
- 1 = EFN and the current practices are expected to provide the same level of utility to the users, meaning that farmers could choose either of the two technologies.
- 2 = EFN is expected to provide higher utility to the farmers than the current practice and that farmers are likely to replace their current practices with EFNs.

μ_i in Eq. 2 is assumed to be normally distributed ($\mu_i \sim N(0, 1)$) and is interpreted as the unobservable component of the farmers' propensity to be in any of the three categories; X_i is a vector of independent variables such as a farmers' demographic characteristics and the characteristics of the technologies. The weight of the ranked attribute is then calculated by multiplying the rank by 0.2 since five scales were used. Thus, an attribute weight varies from 0 to 1.

We estimated five separate probit models, one for each of the four attributes of a new innovation: (1) perceived performance, (2) perceived ease of use, (3) perceived social pressure, and (4) perceived external support, and one model for the overall perceptions about the use of EFNs using the aggregated perception index.

2.6 Review of variables used in the model

'**Gender**' is a binary variable that takes the value 0 for women and 1 for men. We assumed that men's contact with extension service had been higher than with women's (Adékambi et al. 2010). This is likely to result in greater opportunity to have knowledge about the use and benefits of EFNs and access to participating in the free EFN trial phases and net distribution. Therefore, we would expect men to have more positive perceptions about the adoption of EFNs than women (Table 4).

'**Household size**' is introduced as an indicator of livelihood pressure. According to Chayanov's peasant economic theory, the higher the pressure, the higher the farmers need to adopt innovative technologies (Rahman 2003). This should be true where land constraints are met, and we expect a positive correlation between household size and perceptions about the EFN attributes.

Table 4 Expected signs of explanatory variables in the model

Independent variable	Criterion	Expected sign
Gender	Male	+
Education	Level of education	±
Experience	Years	±
Age	Years	±
Membership	Membership of a farmers' association	±
Coastal zone	Intensive production system and better access to supporting extension service office and markets	+
Owner	Ownership of or observer at trial site	±
Land area	Size in hectare	−
Household size	Number of people in a household	+
Total annual income	Income in '000 FCFA[a] (<800, 800–3000, >3000)	+

[a] Franc des Colonies Françaises d'Afrique = currency used in Benin: FCFA 1 = Euro 0.0015 or USD 0.002

'**Income**' is an indicator of a farmers' capacity to pay for a new technology themselves. Farmers with higher income are assumed to take greater risks and absorb shocks should the new technology fail (Dercon and Christiaensen 2011), and we would therefore expect a positive relationship between income and perception toward EFN attributes.

According to Rahman (2003) and Chianu et al. (2006), '**education**' improves access to information and potentially improves understanding and interpreting the attributes of new technologies. We therefore hypothesize that a higher level of education will lead to a greater awareness of hazards related to the use of synthetic pesticides and that it has a positive influence on perceptions.

The variable '**experience**,' measured as number of years of vegetable farming practiced, is included in the model as a proxy measure of the farmers' skills in decision making leading to a positive impact on adopting a new technology (Rahman 2003; Adégbola 2010; Adékambi et al. 2010; Van den Berg 2013). The longer the farmers' experience in vegetable farming, the higher should be the skills in analyzing the relevance of a new technology. As such we would expect a positive correlation between experience and perceptions. However, if a farmer has long-term positive experiences with the current practice, he or she might also express a negative preference for adopting a new technology.

'**Age**' is a common variable influencing farmers' perceptions toward an agricultural innovation (Kariyasa and Dewi 2013; Obayelu et al. 2014) and is likely to be related to experience. Experience in vegetable production might increase with age and might hence have a positive impact on the attitudes toward the attributes of EFNs and their rate of adoption. On the other hand, younger farmers might be more able to learn about a new technology, as their level of education is often higher than that of the older generations and also might be more able to provide the labor required to set up and change the nets. In addition, younger farmers are often less risk adverse and therefore more likely to adopt a new technology (Van den Berg 2013).

We used the variable '**membership of farmers' association**' as a proxy for access to extension services. It was coded 1 when the farmer was a member and 0 otherwise. Participating in a farmers' association increases the opportunity to diversify information sources, and this should result in higher adoption rate of new technologies (Feder et al. 1985; Goswami and Basu 2011; Barungi et al. 2013). The level and quality of information, however, will have depended on the interactions between the informants and information seekers (Halgin and College 2008). It is assumed that farmers are more likely to adopt a new technology when they have sufficient prior information (Feder et al. 1985; Saha et al. 1994; Saltiel et al. 1994; Dimara and Skuras 2003; Adégbola and Gardebroek 2007). The perception about EFN adoption should be positive if the needs have been met and negative otherwise.

Also related to access to extension services is the location ('**zone**') of farmers. Farmers whose trial-implementing sites are closer to extension workers' offices are presumed to have had easier access to information and subsidies and are expected to have formed a positive opinion about EFNs. Farmers in the coastal zone are closer to extensions services, and we expect that the easier it is for them to receive external help, the more favorable will be their perceptions toward EFNs. Furthermore, because farmers in the coastal zone practice traditional intensive production which is needed for exotic vegetable production, and farmers in the inland zone practice extensive production, we expect that farmers in the coastal zone will have more favorable perceptions toward the use of EFNs than farmers in the inland zone.

Participation in on-farm trials and field schools usually leads to higher adoption rates (Orr and Ritchie 2004; Amudavi et al. 2009; Kabir and Rainis 2014). Here we investigated

Table 5 Characteristics of the sample and explanatory model variables ($N = 214$)

Variables	N	Percentage
Research zone		
Coastal zone	112	52
Inland zone	102	48
Farmers' status about the trial site		
Owner	90	42
Observer	124	58
Gender		
Male	204	95
Female	10	5
Education (number in brackets = total number of school years)		
No formal schooling	81	38
Achieved primary school (6)	44	21
Completed year 10	37	17
Completed year 13	51	24
Any level of university	1	<1
Age		
21–40	101	47
41–60	92	43
>60	21	10
Land area allocated to vegetable production (ha)		
0.01–0.5	126	59
0.51–1	46	22
1.1–3	37	17
>3	5	2
Total annual household income (FCFA[a])		
≤800,000	97	45
800,001–3000,000	86	40
>3000,000	31	15
Membership in farmers' association		
Yes	107	50
No	107	50
Experience in vegetable growing (years)		
1–10	138	64
11–20	59	28
21–30	12	6
>30	5	2
Household size		
≤5 persons	91	43
>5 persons	123	57

[a] Franc des Colonies Françaises d'Afrique = currency used in Benin: FCFA 1 = Euro 0.0015 or USD 0.002

two types of participation in on-farm trials of the EFNs: those who own the site on which the trials are being carried out (coded 1) and those who come from neighboring farms and who just observed (coded 0). The '**owner**' of a trial site had been expected to bear the costs of all vegetable production inputs (fertilizer, watering, herbicides, among others) except the seeds and the nets themselves and should have expected an increasing return on investment. The observers at the site, however, would not have received such benefits, and adoption would have been associated with absorption of all costs associated with EFNs, which expected would lower the rate at which they adopted the nets.

The EFNs were distributed to the farmers, so they could cover seven plots of 1.5 m × 8 m each. Without knowledge about any other use strategy, most farmers with a '**land area**' exceeding 3 ha would be expected to reject the adoption of EFNs. Therefore, we expected a negative correlation between land area and perceptions about the EFN attributes and thus the likelihood of adopting EFNs, although other research has shown that farmers with larger cultivated land areas were more likely to adopt other IPM practices for vegetable production (e.g., Kabir and Rainis 2014).

3 Results

3.1 Key socioeconomic characteristics of the farmers

Only 5 % of the farmers were women, probably reflecting a selection bias because few women were included in the original network of farmers. The relatively high level of formal education could be explained by the mass involvement of graduate but jobless youth. Although many respondents where illiterate (38 %), a relatively high level of formal education was noticed among the remainders. Indeed, 17 % completed Year 10, while 24 % had completed Year 13 (Table 5) compared to the national mean of 1.3 and 7.6 %, respectively (INSAE 2011). The sample was divided into three age categories with the largest category being respondents between 21 and 40 years old (47 %) and a few (10 %) over 60 who were mostly retired.

Most farmers (81 %) were smallholder with farm sizes of no more than 1 ha. This was the preferred group of our study as EFNs have not been trialed in areas of more than 3 ha. The EFNs distributed to farmers were able to cover seven plots of 12 m^2 each, so netting larger plots would have required the farmers to have purchased more material themselves.

Almost two-thirds of the respondents had less than 10 years of experience, suggesting that most farmers may have had limited skill levels when it came to making decisions about EFNs (Rahman 2003; Adégbola 2010; Adékambi et al. 2010). Nearly 60 % of respondents lived in households of six or more people.

3.2 Overall perception index

Mixed results were found for the overall perception index of farmers (Table 6). Using the criteria above, only 18 % of farmers perceived EFNs as having advantages over current practices (Group 1). Thirty-five percent of the respondents thought that using EFNs would result in a loss compared to current practices, and thus would reject EFNs (Group 2). The majority (47 %, Group 3) thought that the two technologies would provide similar benefits.

Farmers in the first group gave the performance of EFNs as their highest priority (48 %), followed by external support (39 %). Farmers in Group 2 saw advantages of EFNs

Table 6 Farmer distribution across groups and their overall perception index of EFN attributes ($n = 214$)

Farmers' perceptions about the use of EFNs	Group	Percentage	Overall perception index
Expect higher utility from EFNs than from current practice	1	18	0.74
Expect higher utility from current practice than from EFNs	2	35	0.65
Expect the same utility from EFNs and current practice	3	47	0.57

Current practice = exclusive use of insecticides

Table 7 Farmers' opinions about EFN attributes across the three groups ($n = 214$)

Attributes	Expect higher utility from EFNs than from current practice (1)		Expect higher utility from current practice than from EFNs (2)		Expect the same utility from EFNs and current practice (3)	
	N	%	*N*	%	*N*	%
Performance	18	48	18	24	15	15
Ease of use	3	8	5	7	2	2
Social pressure	2	5	19	25	8	8
External support	15	39	33	44	76	75
Total	38	100	75	100	101	100

Current practice = exclusive use of insecticides

mainly because of external support (44 %), followed by social pressure and performance (Table 7). In this group, only one quarter considered performance to be important. Farmers in the third group emphasized external support as being the most important attribute (75 %), followed by 15 % who ranked performance as an important attribute. The ease of use was not seen as very important by farmers in all three groups.

3.3 Determinants of farmers' perceptions about EFNs

The null hypothesis of the ordered probit model estimation for farmers' perceptions toward the adoption of EFNs was that none of the model coefficients would vary between the groups for any of the attributes. The log-likelihood ratio statistic is higher than the critical value of Chi-square distribution at 11 degrees of freedom (24.73; Table 8). Therefore, farmers' overall perception toward the use of EFNs (far right column in Table 8) was significantly influenced by zone, ownership, and land area.

Overall farmers in the coastal zone had a more favorable opinion about EFNs than those inland, particularly shown by their greater approval of the ease of use and the level of external support for the adoption of the nets, although they had poorer opinions about the performance of EFNs.

Farmers who were owners of the trial sites also had a more favorable view of the external support and also the social pressure than the observers. Farmers who were members of farmers associations thought more highly of the performance of EFNs and the external support than those who were not. Farmers owning small plots of land and those with few household members thought more favorably about the nets' ease of use than those

Table 8 Results from an ordered probit model of farmers' opinions about EFNs

Independent variables	Dependent variables				
	Performance	Ease of use	Social pressure	External support	Overall EFN perception
Coastal zone	−0.356**	0.788***	−0.021	0.608***	0.355**
Membership	0.545***	0.238	0.185	0.308*	0.212
Owner	−0.069	0.155	0.898***	0.494***	0.773***
Land area	0.032	−0.086***	0.045	−0.036	−0.059*
Household size	0.007	−0.053**	−0.016	−0.018	−0.024
Education	0.011	−0.062	−0.101*	−0.107**	−0.048
Experience	−0.007	0.017	−0.008	−0.021*	−0.014
Male	−0.426	0.375	0.406	0.394	0.019
Income	5.18e−08*	4.91e−08	2.68e−08	4.24e−08	4.69e−08
Pseudo R^2	0.048	0.097	0.085	0.098	0.085

*** Significant at 1 % ($p < 0.01$); ** significant at 5 % ($p < 0.05$); * significant at 10 % ($p < 0.1$)

with large plots and large families. Better educated farmers felt less social pressure and felt they needed less external support than those lacking education. Farmers with longer experience in vegetable production also felt they needed less external support than those with less experience. Gender and annual total income from vegetables did not influence farmers' perceptions about the nets at all. The variable age was dropped from the model as it was highly correlated with the variable experience.

4 Discussion

4.1 Overall perceptions about the potential adoption of EFNs

According to the overall perception index, just 18 % of the interviewed farmers would actively prefer to use EFNs over their current insecticide-dependent practice. This minority of farmers could be considered potential early adopters of EFNs and is consistent with the generally low adoption rate of IPM practices in developing countries (Parsa et al. 2014) but does show that there is already a market for nets among nearly a fifth of the farmers sampled. This result is lower than the adoption rate of 37 % for improved yam diffusion (Adégbola and Adékambi 2006) and 26 % for Nerica rice (Africa Rice Center 2008) in Benin, and this may be because the extent of investment, increase in labor costs and the change required to the overall production with nets was much higher than for the other innovations. This low rate also reflects a risk-averse attitude among many farmers with respect to adoption of new technologies (Feder et al. 1985; Marra et al. 2003; Dercon and Christiaensen 2011). Length of time since the innovation was first proposed to farmers may also have had an effect on the low percentage of farmers preferring EFNs. EFNs have been promoted in the region for just 2 years, less than half the 5 years recommended for assessment of the costs and benefits of a new technology (Prochaska and Di Clemente 1982). Yam and rice innovations, for instance, have been promoted for much longer

(7 years). Thus, despite the relatively short time over which EFNs have been promoted, uptake by farmers is sufficient to encourage continued promotion. Indeed, one could argue that understanding heterogeneity of uptake at this early stage is useful for targeting investments in promotion of those sectors least persuaded of the benefits.

Acceptance and use of agro-ecological technologies, particularly those requiring external and purchased inputs, commonly leads to heterogeneity among potential adopters because the technologies are context specific (Lee 2005). We also found such heterogeneity among farmers' attitudes toward EFNs. As expected, farmers who are the owners of the trial sites had a more favorable attitude toward the use of EFNs than farmers who only participated in the net demonstrations. This is probably because the owners were self-selected and showed a particular interested in EFNs in the first place which they are unlikely to have done if they had expected a negative outcome. Also farmers in the inland zone, having more land available than farmers in the coastal zone, were less likely to adopt EFNs than those near the coast. This is consistent with the observation that land area also negatively affects farmers' attitudes toward the nets. The current trial size (at most 168 m^2 covered) was less than a third of the area of the inland farms (at least 552 m^2), so these farmers may think that the nets are not easy to apply to their more extensive production systems despite good evidence of the benefits associated with the use of EFNs (Filliastre Roux 2012). This suggests that trials are needed over larger areas to demonstrate their efficacy and that the benefits are still applicable over larger areas.

4.2 Perceived performance of EFNs

Following Venkatesh's model (2003) and extending it by one parameter (external support; see the framework section), we were able to assess preferences for different characteristics of the nets, as discussed here, in addition to the overall preferences and likelihood of adoption. This sheds more detailed light on why farmers would adopt the nets and what could be improved to increase farmers' positive perception, underlining the usefulness of the applied framework.

A quarter of those farmers with an overall positive perception of the nets expected improved performance. Higher performance/productivity means higher income, and therefore, this attribute was the strongest reason for accepting and using the new technology (Venkatesh et al. 2003). Three factors affected attitudes toward performance of the nets. First, farmers with a relatively high income from vegetables felt more favorably toward the performance of EFNs than poorer farmers. The positive influence of high income on farmers' opinions about EFNs and their likelihood of adopting new agricultural technologies have been underlined in previous studies (Saltiel et al. 1994; Somda et al. 2002; Lee 2005; Ding et al. 2011). Also farmers with high farm incomes could more easily support access to private extension service demonstrations, on-farm trials and field schools.

Farmers who were members of farmer associations also had more positive attitudes toward the nets' performance than those who were not members. This could be because members of such organizations have had better access to relevant information about EFNs and were thus better able to judge whether adoption of the new technology would lead to improved performance (e.g., Feder et al. 1985; Saha et al. 1994; Saltiel et al. 1994; Kabunga et al. 2012).

Third, coastal zone farmers had significantly poorer opinions of performance than those from the inland zone. This may be because the time required for handling the nets was higher than they expected. Also, under project rules, inputs such as fertilizers were limited. As farmers in the coastal zone would usually use much more inputs than farmers in the inland zone (Martin et al. 2006; Simon et al. 2014), their profits may have been lower than they had anticipated. Mistrust of EFNs among the coastal farmers may be restored if they can be made aware that use of EFNs for cabbage protection can result in a significant reduction in insecticides costs (USD 2310 per hectare) and an increase of income of USD 751 per hectare (Vidogbéna et al. 2015a).

4.3 Perceived ease of use of EFNs

Farmers are conscious about the labor requirements for effective use of EFNs. The time they need to spend erecting the nets incurs opportunity costs because they have less time for off-farm activities. All farmers perceived the use of EFNs as not easy, probably because of the additional effort required for their use compared to simply spraying insecticides (Vidogbéna et al. 2015b). EFNs need to be set up and removed once or twice a week, usually in the morning and in afternoon, and farmers said that rural out-migration of young people has made it increasingly difficult to hire additional labor (Simon et al. 2014).

The positive attitudes of coastal zone farmers and the negative perceptions among farmers with larger farms for the ease of use of EFNs are closely related to the availability of labor and the amount of effort required managing nets. The negative impact of household size is surprising since one would expect that the larger the household the more labor would be available to set up the nets. However, this finding could be because more and more people, especially the younger ones, if not out-migrating, prefer to engage in off-farm activities for income diversification while smaller households may rely more fully on farming for their livelihood.

4.4 Perceived social pressure to adopt EFNs

The attribute 'social pressure' is derived from subjective norms and is not related to productivity. Social pressure occurs because farmers face pressure from neighbors and other influential people in their networks (Case 1992; Hallam et al. 2012). A positive influence with regard to EFN use means that the expectations of the influential people (mainly opinion leaders) within the networks are being met. The highly significant correlation between social influence and ownership of plots is promising since its shows that the decisions of targeted farmers are free of negative influences of people in their community, such as other farmers or those with power (e.g., elders, initiators of farmers' associations, main donor within the associations). The positive influence could also be because the self-selected farmers who offered their farms as trial locations are among those people with power and so less affected by social pressure. This is also consistent with the positive influence of education on this variable.

4.5 Perceived external support when adopting EFNs

The perceived availability of external support had a major influence on attitudes. As expected, farmers in the coastal zone felt that they had better access to external support than farmers in the inland zone because access is easier and the population density higher. The owners of trial sites also had positive perceptions of external support, which is not surprising given that extension officers had to be in close contact with them to organize the on-farm trials as well as delivering the nets and seeds required for the trials. Interestingly, more experienced and educated farmers were less concerned about external support than those who were relatively new to farming or were less well-educated. Presumably this is because these farmers felt their experience and education meant less need for external support. However, it could mean that external support needs to be strengthened in order to inform these farmers of the advantages of EFNs over their current practice so they are persuaded to adopt them. In fact, strengthening external support could shift those farmers who think that the nets and the current practices result in the same utility (Group 3, Table 7) and who largely think that external support is the most important attribute, into the group of farmers who thought that the nets bring advantages.

4.6 Policy implications

The results of the EFN trial were based on networks within which farmers participated under different status (owners vs observers/non-owners) which resulted in heterogeneous perceptions about the nets. Exposure to information is not the same as knowledge—awareness (without knowledge) can be distinguished from the deeper understanding of the practicalities of adopting an innovation (Kabunga et al. 2012). The trial process evidently also meant that owners knew much more about the practicability and benefits of the nets compared to the participants. Participants often missed information delivered by the technicians at some critical periods because they were otherwise occupied or could not afford to travel (they had to travel every day on the respective users' sites). Thus, higher involvement of farmers rendered possible by user status (owner of trial site vs participant) evidently altered their adoption attitudes. Small-scale farmers, toward whom the EFN diffusion program was biased, had particularly positive attitudes toward EFNs. Thus, if EFNs are to be more widely adopted, support will continue to be required with external support being extended to many more farmers before they will adopt the practice of their own volition. These observations also suggest that the technicians need to pay careful attention to ensuring that the participants do gain experiential knowledge in addition to awareness. There is room for more detailed research into which participants were most likely to adopt EFNs and the nature of the experience that led them to that conclusion.

Another factor likely to increase adoption of EFNs is the development of a credit and warranty scheme that could be offered to small-scale farmers, at least for the first purchase. While income did not influence the overall perception of EFNs, it did affect expectations of performance with wealthier farmers expecting improved productivity from nets. Given the research showing the benefits of nets, adoption of nets would then increase their wealth relative to other farmers. Certainly, a trial in which finance for nets was made available to farmers under various conditions would be worth conducting, targeting particularly those sectors of the population likely to have least access to start-up capital, such as women.

Another area that needs more research is the flows of impacts resulting from technology introduction and not just a snapshot of this flow, focusing mainly on early adopters and those who may be affected through spillover effects. Best practice or policy needs to be more explicitly incorporated into the models and not just the binary choices for adoption. Moreover, the understanding of market issues should be deepened and included in the models to improve explanations of farmers' current attitudes toward EFNs. Indeed, a rejection of an agro-ecological innovation that has been proven to provide a net benefit over prevailing practices appears unexpected but understandable basing on the absence of separate markets for organic or healthy products in Benin.

Finally, this study identifies the farmers currently least likely to adopt EFNs and therefore those who should be the focus of future extension programs. In particular, there is a need to demonstrate the cost-effectiveness of EFNs on larger plots inland, taking into account the issues of labor shortage and limited access to external support identified in the current research. Further technological improvements that reduce labor requirements and increase performance would also enhance adoption. To an extent, 2 years of extension has already been influential among farmers in the coastal zone, and adoption is more likely to expand there than inland because trials there have not yet been applied with sufficient frequency at a whole-of-farm level.

5 Conclusions

The use of eco-friendly nets as an alternative to excessive use of synthetic pesticides for vegetable production has been trialed with smallholder farmers in Benin. This study reveals heterogeneity in the perception of eco-friendly nets users in Benin. For the 18 % of farmers who were receptive to the adoption of eco-friendly nets, external support (easy access to knowledge and finance) was the main incentive toward their use. This finding suggests that, for a full acceptance and use of agro-ecological innovations by small-scale farmers, more emphasis should be put on technical and financial issues (correct information at right time to the right people, credit and insurance schemes among others). Knowledge and land area allocated to vegetables were the major factors influencing attitudes toward adoption of eco-friendly nets by the farmers. Research that improves extension approaches and enhances ease and effectiveness of net use should be combined with expansion of the trial program to more sites of adoption of eco-friendly nets is to be accelerated.

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