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The adoption of alley farming and *Mucuna:* lessons for research, development and extension

B. Douthwaite[1,2,*], V.M. Manyong[1], J.D.H. Keatinge[1] and J. Chianu[1]
[1]International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria; [2]IITA c/o L.W. Lambourn & Co. 26 Dingwall Road, CR9 3EE Croydon, United Kingdom; *Author for correspondence (e-mail: *b.douthwaite@cgiar.org)*

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Abstract

This paper evaluates the utility of the 'learning selection' model of the early adoption process, based on a constructivist conceptual framework, to explain farmers' adoption and rejection of two soil-improving technologies – alley farming and the use of *Mucuna* cover crops. The analysis showed that *Mucuna* was more successful than alley farming because: (1) early research and extension took farmers' perceptions more into account when changing from recommending *Mucuna* for soil improvement to weed suppression; (2) it was then introduced into areas where there was a real need for the technology; (3) it gave short-term benefits; and. (4) it was more amenable to farmer modification and adaptation. The analysis also provided support for the conclusion reached elsewhere that separate trials are needed to gather biophysical data, where researchers need to keep a high degree of control, as opposed to adoptability trials where farmers must be able to manage the technology as they wish. The paper also used the learning selection model to derive research and extension guidelines. The close match between these guidelines and the literature suggests that a constructivist perspective in general, and the learning selection model in particular, can provide a useful 'road map' to plan and carry out research and extension.

Introduction

There is a consensus in the scientific literature that one of the most serious constraints facing sub-Saharan agriculture is declining soil fertility, partly as a result of shortening fallow periods due to rapidly increasing population pressure (Kang 1993). In a recent comprehensive review of research on soil fertility in West Africa, Bationo et al. (1998) p. 33, concluded that: "Over the past years a considerable amount of technologies to improve the productive capacity of African soils have been generated. These technologies have not been transferred or implemented by the intended beneficiaries. Further research needs to focus more on the reasons for adoption and non-adoption of presently available technologies to combat nutrient depletion." This paper takes up the challenge by reviewing stakeholders' experiences in West Africa with two soil-improving technologies: the use of *Mucuna pruriens* (velvet bean) that has enjoyed substantial farmer-to-fanner diffusion; and the less successful alley farming. The objective of the paper is to evaluate the utility of the 'learning selection' model of the early adoption process, based on a constructivist conceptual framework, to explain farmers' adoption and rejection of these two technologies, and derive lessons for research and extension.

Methodology and conceptual framework

Case study methodology (Yin 1989) is used in this paper to build descriptions of the extension history and adoption status of both technologies. The data used in the case studies come from the literature, as well as from some new analyses of an existing data-

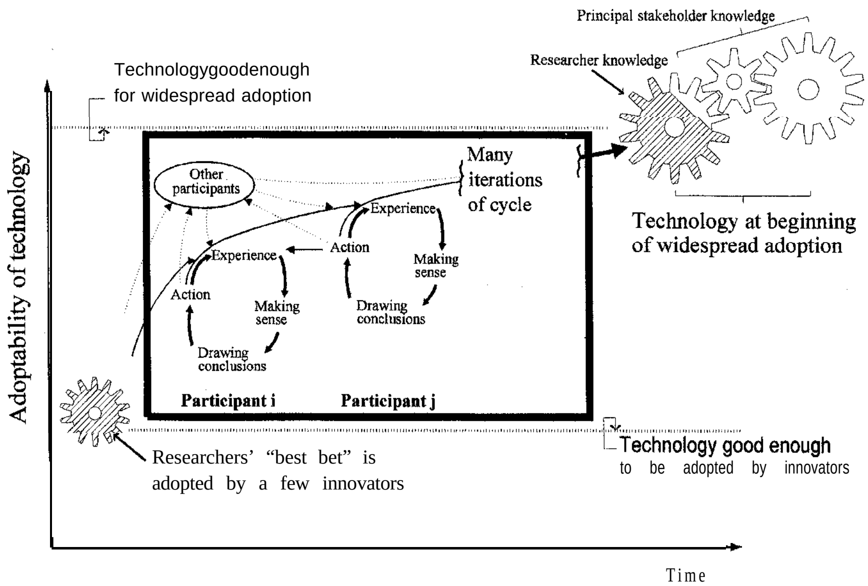

Figure 1. The learning selection model showing how the adoptability of a technology changes during the early adoption phase.

base described in Adesina et al. (1997) and compiled from 1996 surveys of 223 farmers in Nigeria and 288 in Benin. Respondents were chosen randomly from villages where there had been previous testing and extension of agroforestry technologies, including alley farming.

The new analysis carried out is a cross-tabulation of selected variables from the Adesina et al. (1997) data set. The null hypothesis in cross-tabulations is that the variables in the table are independent. The Fisher exact test is used to establish significance because, unlike the more commonly used chi-square test, it can be used if the expected frequency in any cell in a cross-tabulation table is less than 5. The Fisher exact test calculates the exact probability that the observed cell frequencies arose by chance and is more conservative than the Pearson chi-square test that uses the chi-square probability distribution (Everitt 1992).

An analytical framework can help focus case studies by guiding questions asked and suggesting criteria for interpreting the findings (Yin 1989). For the Mucuna and alley farming case studies this framework is provided by the 'learning selection' model developed to explain the 'social construction' of technology during the early stages of adoption (Douthwaite et al.; Douthwaite 2002). The utility of the learning selection model is judged by the insights it produces and the extent to which the conclusions derived match those from the literature.

The learning selection model, depicted schematically in Figure 1, shows two of potentially many participants who are experimenting with a new technology and as a result going through experiential learning cycles. For example, participant *i* might be a farmer or a group of farmers who decide to plant a *Mucuna* cover crop in their fields after seeing a demonstration in their village put on by researchers wishing to demonstrate *Mucuna*'s ability to improve soil fertility. As a result the farmers have their own experiences, based on their needs and their own understanding of how things work and subsequently conclude that *Mucuna* is more useful as a way of suppressing *Imperata*, a grass weed that has caused them to abandon some of their land. The following year they use *Mucuna* to try and reclaim some of this land by cutting the *Imperuta* at the beginning of the rainy season and broadcasting *Mucuna* seed in the hope that it will grow faster than the *Zmperata* and smother it. In so doing they are beginning another learning cycle, the result of which will help them decide whether to continue to plant *Mucuna* in this way.

As Figure 1 shows, other people might also observe the farmers' experiment and as a result go through their own learning cycle, leading to changed perceptions and actions. For example, participant *j* might be a researcher who learns that *Mucuna*'s ability to suppress *Zmperata* is more important to farmers than its ability to improve soil fertility. Learning this might then influence the researcher to carry out further research and recommend changes to the extension approach. Figure 1 shows that the net effect of all these learning selection cycles is that the technology evolves over time and its 'fitness', or adoptability, increases. This evolution occurs as a result of learning selection outcomes which include: modifications to the technology; decisions to continue with these modifications; and the subsequent spread of the technology and changes to it. The resulting increase in fitness leads to more people adopting.

Central to the learning selection model is the seemingly obvious relationship articulated by Lewin (1951) that people's behaviour (B) in learning situations, for example, the actions they take are a function of the interaction between the Person (P) and his or her Environment (E) (B = f(P,E)). The implication of this is that the evolution of a new technology is likely to happen faster if it is introduced to motivated farmers in pilot sites where there is a real need.

The learning selection view that technology evolves during the early adoption process, as a result of interactive learning cycles, suggests an approach for understanding and evaluating early adoption which is:

- Identify and seek explanations for stakeholders' decisions to adopt, continue to use and recommend the technology to others;
- Identify modifications made to the technology by different stakeholders after its first introduction, and find explanations for these changes;
- Determine how these modifications affect adoptability and diffusion;
- Identify the factors that motivate participants to experiment with the technology and how peoples' motivations might affect the actions they take as a result of experiential learning.

The learning selection model is underpinned by a constructivist view of technology, rather than the positivist view implicitly adopted within much of the previous research and development carried out by the Consultative Group on International Agricultural Research (CG) Centres [see Douthwaite et al. for a description of these two opposing views]. In summary, constructivists see reality as socially constructed through a process of people and groups making sense of their experiences, while positivists see reality as something derived from scientific inquiry, which is independent and external to social settings.

Alley farming

Research on alley farming began in 1976 at the International Institute of Tropical Agriculture (IITA). Alley farming is a technology designed to allow farmers to maintain or increase yields without fallow or large amounts of externally-purchased fertilizer. Nitrogen-fixing tree species are planted in rows in the field creating alleys between which crops can be grown. The deeper tree roots work as "pumps" to bring nutrients to the surface, as well as to fix nitrogen. The tree prunings nourish the crops when they decompose and release their nutrients into the soil. Prunings can also be used as a source of fodder for livestock and the trees themselves could supply firewood, stakes and building materials (Kang et al. 1981).

The first results of on-station alley farming trials showed that maize intercropped with avenues of ***Leucaena leucocephala*** could maintain maize yields at 3.8 tonnes/ha/yr while maize yields declined without incorporation of the trees' leaves (Kang et al. 1981). Publication of these results generated much research activity, indicated by a growth in alley farming publications from 9 in 1980 to 130 in 1989 alone (Whittome 1994). A number of other CG centres took up research on alley farming including the International Livestock Centre for Africa (ILCA), now merged and called the International Livestock Research Institute (ILRI), and the International Centre for Research in Agroforestry (ICRAF). Many National Agricultural Research and Extension Services (NARES), particularly in West Africa, became involved in alley farming research and extension activities. In 1989, the Alley Farming Network for Tropical Agriculture (AFNETA) was set up and by 1992 had linked alley farming trials in 20 African countries (Carter).

In 1987, a project called the Adoption Potential of Alley Farming was initiated at IITA. The project found that the considerable on-farm work on alley farming had largely been carried out in areas without either sufficient pressure on land or sufficiently serious soil fertility problems to make the technology attractive to farmers. Secondly, alley farming had a much lower adoption potential than had previously been assumed (Dvorak 1996). The project's findings and an unpublished PhD thesis (Whittome 1994) both helped guide a "substantial reorientation of research on alley farming" (Dvorak 1996) p. viii, that placed emphasis on short-fallow management rather than alley farming ***per*** se. From 1992, IITA has concentrated its short fallow management research effort towards

Table 1. Farmers' adoption (or non adoption) of alley farming in Nigeria as influenced by the sources from which they received information about the technology.

Source of information	Adoption status		
	Adopted or tested in some form	Not planted	Totals
Researcher	134	30	164
Extension	0	3	3
Farmers	4	36	40
Researcher and farmer	1	0	1
Missing			15
Totals	139	69	223

Calculated from the 1996 survey data (Adesina et al. 1997) Fisher exact test P = < 0.0001 (highly significant).

annual cover crops rather than perennials and now carries out most of its research on-farm in locations where farmer circumstances are appropriate for use and adoption. Care is also taken to involve the farmers themselves as active participants in the research.

Adoption status in Nigeria and Benin

By 1992, IITA and ILCA had assisted 435 farmers from 34 villages to plant 471 alley fields in Nigeria and Benin. Levels of assistance varied from research village to research village but often included free provision of seed, seedlings, advice, and in many cases researchers planted alley fields for the farmers (Whittome 1994).

Whittome (1994) carried out an extensive survey of farmers' experiences with alley farming in 29 of the villages and concluded that: "with the exception of Zouzouvou (a village in Benin), alley farming is fundamentally unsuited to the villages where IITA and ILCA have introduced the technology" Whittome (1994) p. 328. This was because land around the research villages was still relatively abundant and as a result farmers were not sufficiently concerned about soil fertility decline to make the technology attractive. This finding tallies with Swinkels and Franze's (1997) research that showed that in western Kenya alley farming was most attractive in areas of high population density, small farms and plentiful labour.

The 1996 survey described in Adesina et al. (1997) chose 14 of the same villages in Nigeria and 13 villages in Benin, including Zouzouvou. An analysis of survey data found that 62% of Nigerian farmers and 25% of Beninois farmers interviewed had adopted alley farming. In Benin, 95% of adopters had had their alley fields established for them by researchers or extension workers, while in Nigeria 90% enjoyed this inducement. In the survey, farmers were classed as adopters if they chose to maintain alley farms, irrespective of who had established the field.

Nearly half of the farmers who adopted in Nigeria subsequently abandoned the technology. The median adoption year was 1986 and no new adoption had occurred after 1990. In Benin, only 7% had abandoned the technology, although the median adoption year was 1993, 7 years later than Nigeria, thus giving farmers less time to evaluate the technology. Tables 1 and 2 show that farmers in both Nigeria and Benin were much less likely to adopt if they heard about the technology from another farmer as compared to a researcher or an extension worker. For example, Table 1 shows that of the 164 farmers who found out about alley farming from researchers, 134 (82%) adopted, while of the 40 farmers who first heard about alley farming from other farmers, only 4 (10%) adopted. This suggests that farmers gave their peers a less favourable description of alley farming than that given by researchers or extension workers.

None of the ILCA or ICRAF papers (Reynolds et al. 1991; David 1995; Swinkels and Franzel 1997) report any farmer-to-farmer diffusion of alley farming in their studies. However, all three papers view participating farmers' decisions to plant more alley fields on their farms as a good indicator of their favourable perceptions of the technique, and its adoption potential. Swinkels and Franzel(1997) found that few farmers expanded their alley fields and said this reflected their lack of confidence in the technology. David (1995) p. 22 wrote: "If the test of farmers' opinion of the technology is their behaviour, the fact that only two farmers [out of eight] had extended their hedges [alley fields] in the eight years since the trials began does not augur well."

Table 2. Farmers' adoption (or non adoption) of alley farming in Benin as influenced by the sources from which they received information about the technology.

Source of information	Adoption status		Totals
	Adopted or tested in some form	Not planted	
Researcher	46	79	125
Extension	26	48	74
Farmers	0	24	24
Other	0	2	2
Missing			63
Totals	72	153	288

Source: Based on 1996 survey data (Adesina et al. 1997) Fisher exact test P = $<$ 0.0001 (highly significant).

The Different Perceptions of Alley Farming

Despite of the lack of farmer adoption it took more than 10 years from the beginning of on-farm experimentation for IITA and ILCA researchers to realise the adoption potential of alley farming was low. From a constructivist perspective, the lessons to be learned from alley farming will come from trying to understand why scientists generally saw alley farming in a more favourable light than farmers for so long.

Researchers

Initially researchers at IITA saw alley farming as attractive because it promised to allow resource-poor farmers to sustainably maintain or increase the productivity of their fields in the face of increased population pressure and environmental degradation, and hence meet one of IITA's most important and long-running objectives. Intellectually, alley farming was attractive because it allowed the cropping and fallow phases to take place concurrently on the same piece of land, thus increasing productivity and reducing the likelihood of environmental damage compared to the traditional bush fallow system (Kang 1993). Researchers saw alley farming as integrating "the art and wisdom of traditional farmers with the efficiency of current science" Kang (1993) p. 142. Early on-station results showed that the technology worked.

Secondly, researchers initially believed that farmers shared their view of the technology because they confused farmers' participation in their trials as real interest and adoption, and took what farmers told them at face value. Whittome (1994) suggests that farmers adopted alley farming because of incentives used to motivate them to establish alley fields on their farms. The tangible incentives included establishing the alley fields for farmers, free labour for weeding, provision of animals, free animal vaccination, free fertilizer and free improved crop varieties. The intangible incentives included farmers' trust of IITA and ILCA which had developed during previous on-farm trials, prospects of employment as village assistants and the prestige of having one's village selected by international institutes. However, no farmer gave these as reasons for why he or she adopted alley farming but instead reiterated the advantages of alley farming emphasised by IITA and ILCA staff, namely, 'improvement in soil fertility',. followed by 'fodder' and 'production of yam stakes' (Whittome 1994). Reynolds et al. (1991) and Swinkels and Franzel (1997) also commented that farmers' responses may well have been biased towards what they thought scientists wanted to hear.

A number of observers state that separate trials are needed (Reynolds et al. 1991; Whittome 1994; Swinkels and Franzel 1997) to gather biophysical data related to technical performance on one hand, and data on adoptability and farmers' perceptions on the other. Reynolds et al. (1991) p. 98 wrote: "A technology's influence on the social organisation of farm households cannot be determined until farmers are free to organise cropping patterns and inputs themselves." This freedom does not exist in biophysical trials which require a high degree of experimental control and hence are not amenable to farmer modifications.

Adoptability trials that encourage farmer modification can also lead to subsequent improvements that increase adoptability. Adesina et al. (1999) report farmer modifications found in the 1996 survey and conclude that their inclusion into the alley farming 'package' would improve the adoptability of the technology. Adesina et al. (1999) also recommend that alley farming should be made more flexible and hence

Table 3. Constraints to adoption of alley farming given by Nigerian farmers.

Constraints to alley cropping	f (%)
High labour demand	44 (60%)
Tree competition with crops	36 (49%)
Root obstructions	31 (42%)
Too many volunteers	23 (31%)
Others	11 (15%)
No constraints	12 (16%)

n = 74, more than one answer allowed. Source: Based on 1996 survey data (Adesina et al. 1997)

more easily adapted by farmers to their local conditions.

Farmers

Despite proven on-station performance and its technical elegance, farmer adoption of alley farming has been disappointing for a number of reasons. Firstly, on-farm yield responses did not match on-station results (Whittome 1994) for reasons that were not possible to pinpoint (Dvorak 1996).

Secondly, as already discussed, with the possible exception of Zouzouvou, alley farming in Nigeria and Benin was introduced into villages without sufficient land scarcity or abundance of labour for the technology to be appropriate. As a result, Nigerian farmers in the 1996 survey gave high labour demand as the main constraint (see Table 3).

Table 4 shows that the labour requirement for land clearance and preparation in an alley field is more than double that of a traditional system, due to the large amount of labour needed to cut down *Leucaena* trees. The table also shows that the labour requirement for crop care is one-third higher, due to the labour required to prune the *Leucaena*. Most farmers in the villages where alley farming was introduced relied on family labour, making the additional labour requirement for pruning at peak season particularly difficult to fulfil. The additional 70.5 man-days per hectare needed to prepare an alley field for planting, although required during the off-season when farmers may be under-employed, still comes with a cost because leisure has an opportunity cost and off-farm employment may be possible in some cases. Assuming an opportunity cost of labour during the peak period is the daily wage rate of N150 per day (including food), and N75 per day during the off-season, then the additional labour required for alley farming costs 5,688 N/year for which a farmer could buy about 83 kg of N. According to data collated by Whittome (1994), the prunings from *Leucaena* yield 160-250 kg N/ha/yr. Therefore, in monetary terms, the fertilising effect of *Leucaena* justifies the additional labour required, suggesting that labour shortage is preventing farmers from engaging in this otherwise economically beneficial activity. The perceptions of Moses Ogunwole, an alley farmer from the relatively land-surplus village of Iwo-Ate, Nigeria, support this conclusion: “Yes, there is benefit. I have grown maize and cassava in my alley field for 10 years and the yield has not fallen, as I would expect. But given the choice again, I would not adopt. It is too much work to cut the trees and weed out volunteers. I would like to return this land to my normal fallow system but that is difficult because even cutting these trees back 4 times and burning them is not enough to kill them.”

The 1996 survey found that in response to labour constraints all adopting farmers had introduced a fallow period of (on average) 3 years following 3 years of cropping (Adesina et al. 1997). In so doing, farmers were attempting to manage the alley fields in the same way as they managed their other fields and were thus rejecting the core feature of alley farming of combining cropped land and fallow land in the same field.

The ICRAF and ILCA papers also show that labour shortage is a major constraint. David (1995) said labour shortage was the main reason cited by farmers for their non-expansion of the technology. Reynolds et al. (1991) found that half of adopters said that finding the labour for pruning was the most difficult aspect of alley farming.

Mucuna

Introduction and adoption in Benin

Mucuna pruriens is a herbaceous legume which was first introduced into Africa in the 1920s and was grown on several experimental stations in Nigeria as improved fallow and in relay with maize and cassava. Agboola (1975) reported that farmers did not widely adopt *Mucuna* in spite of much publicity from the Ministry of Agriculture in Nigeria. Nevertheless, some diffusion of the plant did occur. For example, *Mucuna* is grown in Ghana and farmers found ways of processing and cooking it to reduce the L-Dopa toxin levels in the seed (Versteeg et al. 1998).

Table 4. Additional labour requirements (man-days per hectare) placed on farmers by alley cropping maize and cassava when the alley field is left fallow for 3 years.

Operation	Alley farming	Traditional bush fallow	Timing
Land preparation			
Under brush clearance	11.1	26.6	Off peak
Felling trees	83.2	n.a.	Off peak
Burning and destumping	34.2	38	Off peak
Subtotal	135.1	64.6	
Crop care			
Crop planting	28.4	23	Peak
Weeding	81.7	75.8	Peak
Thinning the crop	3.6	4.3	Peak
Pruning the trees	23.4	n.a.	Peak
Subtotal	137.1	103.1	

Note: 1 day = 6 man-hours; n.a. = not applicable. Source: Calculated based on data West Bank III fallow management trial, IITA, Ibadan, Nigeria.

In 1986, when the Recherche Appliquée en Milieu Réel (RAMR) project of the Institut National des Recherches Agricoles du Bénin (INRAB) began a participatory evaluation of soil fertility technologies, Mucuna was chosen along with alley farming, pigeon pea hedgerows, and inorganic-N fertilizer. INRAB was guided and supported in the RAMR project by IITA and the Royal Tropical Institute of the Netherlands. Demonstration plots were established in pilot villages chosen in Mono Province, including Zouzouvou. After two years of demonstrations, farmers were given the chance to evaluate the technologies themselves. Twenty chose to try *Mucuna*, of which 14 successfully established a dense stand. In their subsequent learning cycles, farmers discovered that *Mucuna* was very effective at suppressing one of their most serious weeds, *Imperata cylindrica. lmperata* takes hold as the length of fallows and soil fertility decline and can force farmers to abandon their land. Subsequent farmer-to-farmer exchange of experience led to 103 farmers planting *Mucuna* the following year (Versteeg and Koudokpon 1990), giving a diffu-
1 sion ratio of about 1 to 7. Galiba et al. (1998) found a similar diffusion rate for later extension efforts. In both cases, farmers decided to adopt largely on the recommendation of their neighbours but were given seed by the extension services.

The government extension service found out about the farmer adoption and began testing *Mucuna*'s weed suppression abilities with other farmers. National NGOs became involved, including the Regional Centre for Development of Health and the Projet de développement de l'tlevage dans le Borgou Est. This testing was extended to other southern provinces in 1991 and the number of farmers involved grew to 500. This early success in identifying a promising technology and then targeting it to farmers with *Imperata* problems has been attributed to a very close researcher-extensionist-farmer interaction, assisted by the involvement of NGOs. Then, in 1992, the large international NGO Sasakawa Global 2000 (SG 2000) became involved.

SG 2000 started by buying 4 t of *Mucuna* seed from farmers to give to 128 farmers in other provinces where *Imperata* infestation and soil depletion were problems (Vissoh et al. 1998). The NGO produced a technical bulletin on *Mucuna* establishment to guide extension workers. SG 2000 used existing government extension services, working with Zone Extension Officers who fed two simple extension recommendations to Village Extension Workers who in turn passed them onto Farmer Contact Groups (Galiba et al. 1998). The two recommendations were to plant *Mucuna:* 1) as a pure stand to rehabilitate badly depleted soils abandoned to *Imperata;* and 2) as a relay with maize to provide a cover crop in the dry season (Vissoh et al. 1998). In choosing this approach SG 2000 were attempting to "spread the message to achieve diffusion and adoption of the innovation by as many smallholders as possible," which is Ruthenberg's (1985) p. 110 description of the classic Green Revolution approach to agricultural extension. Experience from the Green Revolution in Asia suggests that hierarchical extension systems based on NARS are effective at achieving rapid adoption of simple, flexible, seed-based technologies (Douthwaite et al.

2001b), but not more complex, resource management ones.

SG 2000 continued with the strategy of planting demonstration plots in villages and buying Mucuna seed from collaborating farmers to give to new farmers, increasing the amount of seed it purchased each year. SG 2000 bought seed from farmers at 50 CFA/kg ($0.08/kg, 1995 price), providing farmers with a useful income and an incentive to adopt. In 1995, SG 2000 reduced the size of their demonstration plots from 0.5 ha to 0.05 ha, allowing them to increase their number from 1,000 to 10,000. Plots were planted throughout the country, even in areas where ***Imperata*** infestation was not a problem. SG 2000 bought 15 t of seed in 1995 to plant the plots and for free redistribution. Vissoh et al. (1998) calculated a benefit-cost ratio of growing ***Mucuna*** of 3.5 when farmers could sell their ***Mucuna*** seed, a benefit cost-ratio of 1.24 if they did not, and a ratio of just 0.62 for the traditional system. By 1996, SG 2000 estimated that 10,000 farmers were growing ***Mucuna*** (Galiba et al. 1998).

Manyong et al. (1999) report results from a 1998 survey of 580 farmers in areas where ***Mucuna*** had recently been introduced. They found that adoption rate, measured in terms of area planted to ***Mucuna,*** rose steadily from 1991 and peaked in 1996 at 5%, but then fell by more than one-quarter in 1997. This fall was because SG 2000 stopped buying large amounts of ***Mucuna*** seed in 1996, leading to a collapse in the market. The survey found that three-quarters of farmers were adopting to control ***Zmperata.***

Different **Perceptions** of Mucuna

Again, a constructivist perspective suggests that valuable lessons can be learnt from identifying the differences in perceptions of ***Mucuna*** held by researchers and farmers, and the reasons for them.

Researchers

Just as with alley farming, researchers believed that ***Mucuna's*** main attraction to farmers was its ability to improve soil fertility. This perception came from research that showed ***Mucuna*** could restore fertility on very depleted soils. In one experiment, farmers increased their maize yields from 480 kg/ha to 1140 kg/ha (Versteeg et al. 1998).

However, as already seen, most farmers adopted ***Mucuna*** not to improve soil fertility but rather to control the weed ***Zmperata.*** Unlike the alley farming trials, though, the introduction of ***Mucuna*** to Benin was carried out as an extension rather than a research activity. As a result, farmers were given a choice of technologies, and demonstration plots were set up to demonstrate, not for scientists to gather biophysical data. Vissoh et al. (1998) p. 11 wrote that the farmers' discovery of the weed-suppressing abilities of ***Mucuna*** was 'an unexpected benefit' for scientists. However, because the project was driven more by the needs of farmers than of researchers, the project was flexible enough to reappraise its view of ***Mucuna*** and to start to promote it in areas that suffered from ***Imperata*** infestations. This flexibility allowed learning selection to take place, i.e., interactive experiential learning between farmers and researchers. This led to a modification that increased the adoptability and spread of the improvement.

Most of the flexibility and learning selection stopped after SG 2000 became involved in promoting the technology because of the NGO's use of a top-down approach. This approach disseminated a simple, fixed, message and did not look for local modifications. In so doing researchers and extensionists missed out on further opportunities to learn, refine and improve the adoptability of the technology.

Farmers

In 1998, farmers in 3 southern provinces of Benin were interviewed to assess their perceptions of *Mucuna* as a soil fertility improving technology (Honlonkou et al. 1999). One finding was that while farmers "derived more satisfaction in adopting ***Mucuna*** than in applying fertilizers, except on rented land" Honlonkou et al. (1999) p. 16 they did not generally use ***Mucuna*** as a direct replacement for inorganic fertilizer. Thirty six percent of farmers were using inorganic fertilizer compared to 7% using ***Mucuna*** (Honlonkou et al. 1999), largely because ***Mucuna*** prevented farmers from growing a second food crop (Manyong et al. 1996) while inorganic fertilizer did not carry this constraint. Farmers were calculating that the immediate opportunity cost of the lost crop was higher than the future benefits of a ***Mucuna*** cover crop. However, if ***Mucuna*** helps them recover land by controlling ***Zmperata,*** then there is no short-term cost in terms of family food production and so adoption made sense.

As with alley farming, the ***Mucuna*** case study shows how artificial incentives that directly or indirectly encourage farmers to adopt can alter their perception of a technology to such an extent that when the incentive is removed, they reject the technology. In the case, SG 2000 provided two linked incentives – giving seed to first-time adopters and purchasing seed from collaborators – and so created an artificial market.

Evaluating the learning selection model as a tool for understanding and explaining adoption patterns

The objective of this paper is to show the utility of the constructivist-based learning selection model in being able to elucidate the adoption patterns of alley farming and ***Mucuna,*** and to generate specific research and extension guidelines.

The learning selection model has clearly proved to be useful. It has helped show that ***Mucuna*** was a more successful technology than alley farming because:

- ***Mucuna*** was simpler and hence it was easier for farmers to adapt it to their existing systems, rather than alley farming which was a new system in itself;
- ***Mucuna*** was introduced into areas with real need and then provided high short-term benefits, including the reclamation of land and reducing family labour for weeding, that motivated farmers to start using the technology. In contrast, alley farming, which has a high labour requirement, was generally promoted in land-abundant areas with labour scarcity where it had very low adoptability potential;
- The early extension of ***Mucuna*** was better matched to farmers' needs because researchers were more participatory and took farmers' perceptions seriously when they realised that farmers valued ***Mucuna's*** weed-controlling qualities higher than its soil-fertility-enhancing ones.

The learning selection model helped show in both case studies that farmers' subsequent actions after adopting are accurate indicators of how farmers really perceive technology, and hence are important indicators of the adoptability of a technology. These indicators include:

- Expansion of a technology from an experimental plot to the wider farm (also identified as an important indicator by Reynolds et al. (1991) and Swinkels and Franzel (1997));
- Farmer-to-farmer diffusion of technology;
- Farmer modification of the technology.

Farmer modification is also important because it can lead to improvements in the 'adoptability' of the technology.

The learning selection model can also help guide research and extension. It supports the participatory paradigm that sees extension as a process of facilitating farmer learning and experimentation (e.g., Van Veldhuizen et al. (1997)) rather than a process where farmers are passive recipients of finished technologies. This emphasis on fostering interactive farmer and researcher experiential learning, together with the evidence from the case studies, allows the following recommendations to be made about how to carry out on-farm research that leads to sustainable adoption.

1. Choose pilot sites where the adoption potential is high because this will motivate farmers to participate, learn, adapt, select and recommend the technology to others.
2. Provide farmers with technologies that are easily understood and are easy to modify, and motivate farmers to experiment by offering a promise of real short-term benefit. The case studies show that technologies that offer medium- and long-term benefits (e.g., improvements in soil fertility) are unlikely to be adopted if they also involve short-term costs;
3. Ensure farmers adopt because of the promise of benefit rather than because of other incentives, e.g., free seed and fertilizer. If farmers adopt for the wrong reasons then the outcomes of their subsequent learning cycles are unlikely to contribute to increasing the adoptability of the technology;
4. Do not try to constrain farmers' learning cycles by placing restrictions on their management practices in adoptability trials. In practice this means carrying out separate trials to assess adoptability and biophysical performance (Reynolds et al. 1991; Swinkels and Franzel 1997).

Conclusions

In this paper the learning selection model, based on a constructivist perspective, led to useful insights and understanding of the contrasting adoption processes of two soil-improving technologies – ***Mucuna*** and alley farming. Many of these insights, derived as they were from the interactive experiential learning cycle at the core of the learning selection model, have also been reached in the literature reviewed in this paper.

Hence a constructivist perspective in general, and the learning selection model in particular, may also help guide research and extension that will better yield real and sustainable improvements in farmers' livelihoods.

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