earthscan

doi:10.3763/ijas.2008.0369

The importance of ecological and socio-technological literacy in R&D priority setting: the case of a fruit innovation system in Guinea, West Africa

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The introduction of farmer participatory approaches over the past decades has to some extent improved the relevance and uptake of research results. While R&D prioritization increasingly involves more stakeholders, including the private sector, policymakers and civil society, building ecological literacy among all stakeholders is urgent, especially for sustainable agricultural development. A case study of an emerging fruit innovation system in Guinea, West Africa, highlights the challenges of supply- and demand-driven approaches to R&D prioritization. Shallow ecological knowledge and a blind faith in 'modern' technologies by scientists and farmers alike distort prioritization. Locally available, appropriate technologies are dismissed in favour of high technologies that are inaccessible to most smallholder growers. Strengthening the ecological literacy of all stakeholders may help to overcome this bias. On the other hand, building socio-technological literacy would allow innovation intermediaries, who typically act as brokers between the demand- and supply-side of technologies, to better understand the social and institutional contexts of technologies and how these affect potential uptake by poor farmers. Member centres of the Consultative Group on International Agricultural Research (CGIAR) could use the notion of ecological and socio-technological literacy to better understand supply and demand of technology and to work more effectively with their partners towards pro-poor and sustainable agricultural development.

Keywords: CGIAR, ecological literacy, learning, R&D priority setting, socio-technological system

Introduction

As one of the social scientists who helped shape the early movement towards participatory research, Bentley (1989) anticipated the challenges of translating farmers' demands into research questions. He concluded that 'researchers participating with small farmers to strengthen, invent or reinvent appropriate technology should understand that farmers have information gaps in certain predictable domains of knowledge' such as insect and disease management, and that 'researchers could help fill these gaps while at the same time learn from farmers to fill some of their own information gaps'. Nearly 20 years later, the Institute of Development Studies organized an international workshop in Brighton, UK, called 'Farmer First Revisited'. In her keynote paper, Jacqueline Ashby (2007: 3) sadly observed that over the years, participation has become a sales pitch to development donors creating 'the distortion of agenda away from the priorities of the poor in science-driven consultations with farmers, where priorities were shaped a priori by supply-driven, commodity-focused research'. Her assessment of the challenges for more equitable and pro-poor

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research indicates that researchers have an interest in encouraging farmers to choose to invest in those technologies developed by researchers. Scientists have learned to parrot the rhetoric of farmer participation, but have not always engaged with farmers.

Following Biggs' (1990) conceptual multiple source of innovations model, various practical initiatives emerged that broadened the innovation base in agriculture. New diagnostic methods to set agricultural research and development (R&D) priorities emerged over the years (Farrington, 2000). Institutional innovations to improve R&D prioritization processes included the establishment of partnerships with non-governmental organizations (NGOs) and producer organizations (Collion & Rondot, 1998; Gilbert, 1990); the emergence of brokers between the supply and demand side of innovation or 'innovation intermediaries' (Howells, 2006; Klerkx & Leeuwis, 2008); the use of information and communication technologies to enhance rural learning and 'self diagnosis' of problems and testable solutions (Burch, 2007; Gupta, 2006; Van Mele, 2006); the development of 'new professionals' through institutional change in higher education, such as the Convergence of Sciences Programme (Nederlof *et al.*, 2007); and new funding mechanisms to make research more relevant to resource-poor farmers' needs (Salahuddin *et al.*, 2008; Waters-Bayer, 2005). All these examples imply a need to change mindsets, institutions and ways to enhance learning for all actors in the system if agricultural R&D prioritization processes are to stimulate socially inclusive and environmentally friendly development. This paper aims to provide insights into how the demand and supply of technologies, with a focus on integrated pest management (IPM), are affected by the level of ecological and socio-technological literacy among the actors in the innovation system.

Ecological and socio-technological literacy

Ecological literacy

Farmers cannot inquire about something they are unaware of. The same is true for researchers, consultants, innovation intermediaries, private businesses and governments. As such, the ecological knowledge or ecoliteracy of actors in an innovation system affects the way they manage natural resources and formulate R&D policies. In the preface of the book *The Cultural Dimension of Development*, Robert Chambers and Paul Richards claim that in many fields indigenous knowledge is far more relevant, valid and useful than had been supposed, and that we need to learn from people before trying to teach them (Chambers & Richards, 1995). Although local people could offer alternative knowledge and perspectives based on their own locally developed practices of resource use (Berkes *et al.*, 2000), mechanisms of knowledge transfer to inform research policy and practice are less clear. As with scientific knowledge, folk knowledge is diffuse, fragmentary and partial (Thompson & Scoones, 1994). In developing countries, knowledge about plant and animal species and their use is often richer among the poorer layers of the society (Pilgrim *et al.*, 2008). However, despite its values, folk knowledge is also constrained by the interests and powers of observation of local people (Bentley & Valencia, 2003). In general, farmers know more about plants, less about insects and less still about plant pathology (Bentley, 1989).

Mechanisms of R&D prioritization processes, and mindsets of those involved, partly determine process outcomes. Despite the rhetoric of being holistic, IPM practitioners have paid relatively little attention to systematically assess local ecological knowledge on pests and their natural enemies (Greathead, 2003; Lenné, 2000; Van Mele, 2008). Scientists and farmers may differ in opinion about the pest status (van Huis & Meerman, 1997). Even among scientists there may be disagreement on the status of beneficial insects: although the role of the predatory weaver ant *Oecophylla* in protecting tree crops from harmful insects has been widely documented (Van Mele, 2008; Way & Khoo, 1992), colleagues at various international research institutes consider weaver ants a pest as they interfere with the efficacy of the solution they are proposing (rightly or not), namely the use of *parasitoids*. Outcomes of R&D prioritization processes therefore not only depend on farmers' ecological knowledge, but also on the mindsets of those involved in the process, be they scientists, consultants, NGO staff or innovation intermediaries.

Socio-technological literacy

Prioritization processes are embedded in socio-technological systems whereby social relations and networks play a crucial role in determining the nature of the resulting technology (Engel, 1997; Geels, 2004; Olsen & Engen, 2007). I refer to socio-technological literacy as the body of knowledge on mechanisms of technology development, dissemination and use within the biophysical, social, institutional, economic and political context. Over the past 20 years, adoption and diffusion of technology has increasingly been seen as a collective evolutionary process that is strongly influenced by the actors involved and institutions shaping their interactions (Leeuwis, 1999; Silverberg, 1991). A socio-technological approach to innovations provides a coherent conceptual multi-level perspective, using insights from sociology, institutional theory and innovation studies (Carlsson *et al.*, 2002; Geels, 2004; Markard & Truffer, 2008). It incorporates the user side in the analysis of innovation processes. It also suggests an analytical distinction between systems, actors involved in them, and the institutions which guide actor's perceptions and activities, and the dynamic interplay between actors and structures. Recently, innovation systems practitioners realized that the focus on the structure of innovation systems has been insufficient and that process analysis or history event analysis are as important for well performing innovation systems (Hekkert *et al.*, 2007).

Participants to the Farmer First Revisited workshop, held in Brighton in December 2007, explored how innovation systems and farmer first approaches in R&D could find common ground (Scoones *et al.*, 2008b). This evolution points to an identified need for a gradual convergence between innovation systems and socio-technological approaches in research.

Combining the two

To increase the impact of R&D for sustainable and socially inclusive agriculture, this paper argues that we need to move beyond the rhetoric and that both ecological and socio-technological literacy of all actors in the system needs strengthening. Andy Hall and colleagues (2004) argued that new agricultural R&D arrangements are needed that are client-responsive, integrated into markets and above all driven by the goal of poverty-focused, sustainable development.

Goal, case selection and methods

Based on a case study from an emerging fruit innovation system in Guinea, West Africa, this paper aims to elucidate how levels of ecological and socio-technological literacy among the various actors in the agricultural innovation system affect the outcomes of R&D prioritization. It presents the challenges to formulating research questions that contribute to sustainable and pro-poor development, and that take into account both the supply and demand of innovation.

Large economic losses due to a complex of African fruit flies, aggravated by recent outbreaks of a devastating new fruit fly, *Bactrocera invadens* (Vayssières *et al.*, 2005) has boosted donor interest in supporting the search for appropriate solutions. The generalist predatory ant *Oecophylla* is effective in controlling fruit flies and is a pro-poor technology that is readily available to African farmers (Van Mele *et al.*, 2007). However, opinions as to the way forward differ among stakeholders, making it a relevant topic to study the dynamics of demand and supply of farm technologies.

To assess the actors, their interactions, level of ecological literacy and perception of problems and solutions at hand for effective fruit fly control, I held informal interviews with scientists, plant protection staff, growers, fruit pickers and staff (both in Guinea and at headquarters in Antwerp, Belgium) of the mango-exporting company (SIPEF) from 2005 to 2007. In October and November 2006, IRAG agronomists and plant protection staff interviewed 100 tree crop growers in the major horticultural zones of Guinea, including Kindia, Kankan and Boké. The objective of the survey was to assess farmers' ecological knowledge and their explicit demand for pest management technologies as a response to a new problem (the invasive fruit fly). Fifteen questions covered orchard management, pests and knowledge on weaver ants, and sources of advice. The questions were based on insights into the local context and similar research conducted during the last decade in various African and Asian countries. Our approach confirmed the importance of having a short questionnaire with open-ended, targeted questions. By being aware of local issues, the interviewers avoided the superficiality that can undermine long questionnaires that fish for information.

The Guinea case study

An emerging fruit innovation system

Mango-based cropping systems in francophone West Africa are very varied with management and varietal composition depending on the local context (Vannière *et al.*, 2004). Mali was the first country in the region to begin exporting mangoes around 1970, followed by Burkina Faso, Senegal and especially Côte d'Ivoire in the 1980s (Rey & Goguey, 1996). In Guinea, market-oriented policies and free movement of people and goods did not emerge until after the death of president Sékou Touré in 1984 (Krebs & Vogel, 1995). Now, only one global trading company (SIPEF) exports mangoes from Guinea to European supermarkets. It abides by the Good Agricultural Practices set by the European Retailers' Association (EUREPGAP) by cashing in on the fact that most local production is organic by default. Besides these intercontinental exports, business people from Côte d'Ivoire cross the border to buy up entire harvests, even arriving in some cases with their own teams of fruit pickers, but this trade is highly variable from one year to the next (Koumandian Camara, personal communication).

Historically, research on fruit crops in West Africa (and many other developing countries) was mainly conducted with support from the French overseas technical cooperation, currently called CIRAD. Research prioritization was mainly driven by external and national experts and little thought given to alternative ways of setting the scientific agenda. Research focused mainly on varietal and agronomic issues (Rey *et al.*, 2004). In Guinea, researcher-extension-farmer linkages have been extremely weak (Adesina & Baidu-Forson, 1995). Currently, the national extension service hangs on a thread, supported by only a few development projects. The national agricultural research institute IRAG, like many other national agricultural research institutions in Africa (Beye, 2002), is aiming towards a more decentralized and demand-led model.

IRAG's fruit research centre (CRA Foulaya) is located in an undulating landscape gifted with ample rainfall and fertile land near Kindia, about 130 km from the capital Conakry. It has been involved in a few projects focusing on tree crops, the most recent one being the regional Sustainable Tree Crops Program (STCP Phase I: 2000–2005), supported by USAID and Kraft Foods, but none paid particular attention to local knowledge. In 2006, I obtained a grant from the US-based Conservation, Food and Health Foundation to start activities with ant-based pest control in tree crops in Benin and Guinea, later on joined by Tanzania. When I first met the director general of IRAG, he was surprised to hear that someone showed an interest in this native ant and that related research was already well advanced in Asia and Australia. Once the project was approved he granted full support and, despite the small budget, mobilized more than 10 of his staff. All were initially unaware of the benefits of weaver ants, some even openly sceptical.

Fruit farmers and perceived pest problems

The growers interviewed were on average 57 years old with 16 years of experience in orchard management. Since the death of Guinea's first president, Sékou Touré, many local government officers have taken up agriculture, as reflected in our survey sample: 25% of participants were administrators or teachers. In West Africa, government officials frequently return to the rural areas and grow tree crops as a retirement strategy. Consequently, many older farmers have not necessarily built up a life-experience and intricate relationship with farming.

One-quarter of the orchards were mango or cashew mono-crops. However, among all orchard growers, 88% grew mango (*Mangifera indica*) followed by 57% cashew (*Anacardium occidentale*), 44% oranges (*Citrus* spp.), 39% avocado (*Persea americana*), 17% cola (*Cola acuminata*) and 15% palm trees. Weeds, insect pests, diseases, lack of access to fertilizers and bush fires were identified as key difficulties. About 86% of the growers spontaneously mentioned insects, especially fruit flies, as their principal pest problem, followed by weaver ants (37%). Other pests included borers (19%), mammals (14%), termites (13%) and scales (12%). Mammals causing damage included squirrels, fruit bats, grasscutters (native rodents) and monkeys.

Few growers managed pests, with only one-tenth of them applying mechanical control against borers and spraying pesticides. Farmers do not have ready access to pesticides and those using them received them through the regional agricultural research centres or a private production and agricultural trading company (SPCIA).

Different answers to similar questions

The opening question as to what farmers know about weaver ants only brought out negative aspects, such as *Oecophylla* rolling up tree leaves and being a nuisance during harvest. When probed to elaborate on what weaver ants actually do to their own trees a slightly different picture emerged (Table 1). The negative perception that ants make the fruit dirty was downplayed from 34% to 12%. Ants protect scale insects (Homoptera: Coccidae) in exchange for their sugary excrements. As these scale insects are mainly clustered on some of the new mango growth flushes and on a small proportion of the fruit, they are clearly visible with the naked eye. Farmers do not know that scales are insects of their own right; some see them as dirt on the fruit. Scientists in particular consider scales as serious pests, and consequently have used ant attendance on scales as an argument to also classify *Oecophylla* as a pest. On the other hand, 26% of the growers highlighted the positive effect of the ants on mango fruit quality. To a more targeted question, 57% reported that *Oecophylla* had a positive effect on fruit quality, such as a higher sugar content, a perception shared by fruit pickers in Benin (Sinzogan *et al.*, 2008). Reasons given for improved quality varied from ants depositing their eggs on the fruit (6%), ants protecting the fruit from pests (24%), and because fruit in orchards with ants is allowed to ripen before being picked (26%).

Superficial interviews would have confirmed existing scientific prejudices that nothing good was to be expected from weaver ants. Over the years, smallholder farmers have become accustomed to emphasizing the negative aspects of their farm enterprise, with outsiders being seen as providers of free technical inputs. Those limited questions we developed allowed IRAG staff to obtain a fresh view on farmers' realities and gradually develop their own ecological literacy.

Farmers' knowledge and explicit demand for technology

Despite the challenges of observing tree crop pests and their natural enemies, 58% of the farmers had observed *Oecophylla* prey on pests, mainly on small insects (52%), followed by winged insects (29%), black ants (8%), worms (4%), scales (3%) and snakes (2%). Most mango orchards in Guinea are mixed cropping systems in which also shorter fruit and nut crops grow, which makes observing pests and natural enemies easier. However, the process of assessing the overall net effect of pest predation is not simple when no systematic testing is done. As a result, the opinions of growers varied considerably (Table 2). Long-term interaction with scientists may help farmers clarify some of their ideas, but there are not enough scientists to go around.

Because *Oecophylla* bites harvesters, many farmers classified the ant as a pest and requested the help of plant protection staff to treat their orchard with pesticides even though over half of

Table 1 Farmers' response to open-ended questions dealing with *Oecophylla*, Guinea, 2006 ($n = 100$). Some farmers gave multiple answers

Farmers' reaction	*What do you know about weaver ants? (%)*	*What do weaver ants do to your crops? (%)*
Make harvest and farm operations difficult	73	73
Roll up leaves	36	44
Make fruit dirty	34	12
Improve the quality of fruit	—	26
Chase away snakes and other pests	18	22
Affect flowering	7	—
Deposit 'eggs' on the fruit	3	—
Affect the development of plants	—	5
I don't know	—	2

the farmers knew the ant preyed on pests. The farmers may not have understood the extent of insect predation (i.e. they may think that the ants only kill trivial numbers of pests) or the farmers may have given greater weight to their own comfort during harvest. This explicit demand for pesticides increased following outbreaks of a new fruit fly species, *Bactrocera invadens*, suggesting that farmers, like everyone else, learn by observing changes in their environment. Shallow knowledge of ecological principles and a blind belief in 'modern' technologies by national scientists and farmers alike seriously influence the demands that farmers express to researchers.

Evolving supply and demand of technology

In my review paper on *Oecophylla* (Van Mele, 2008), and following recurring remarks by scientific peers, I proposed the management of mango scales as one of the areas for collaborative research with farmers. At the time of writing the review, research into local knowledge of African fruit growers and pickers was still on-going. Results from Benin (Sinzogan *et al.*, 2008), Guinea (this paper) and Tanzania (unpublished) reveal that the principal reason for farmers considering weaver ants as a pest is not its relationship with scale insects. In fact, some women fruit pickers in Benin even consider scales on mango as an indicator for top quality: fruit from trees with weaver ants being sweeter and having a longer shelf life. Farmers do not insist on getting rid of the scales, they basically want to reduce the ant nuisance during farm operations. Unlike many other ant species, the bite of *Oecophylla* is not particularly painful and the pain disappears within seconds (Hölldobler & Wilson, 2000). Nevertheless, weaver ants can be a nuisance and such feelings are likely to be stronger when one is not fully aware of the benefits the ants bring. Beninese growers involved in on-farm research changed their negative attitude towards *Oecophylla* when they learnt about the ants' importance in reducing fruit fly damage (Sinzogan *et al.*, 2008). Across Africa, farmers' implicit demand for technology is about addressing the ants' nuisance. The project documented various local practices (Table 3) as part of an on-going effort to enhance South–South learning. As Bentley *et al.* (2007) said 'demand and supply of farm technology are like two sides of an unfolding conversation'.

Table 2 Farmers' perception of *Oecophylla*, Guinea, 2006 ($n = 100$)

Perception	***% of farmers***
Effect of *Oecophylla* on pests	
Reduces pest damage	43
Increases pest damage	24
No opinion	33
Global status of *Oecophylla*	
Pest	69
Beneficial	24
No opinion	7

Discussion

Partnerships

The level at which national economies develop is determined by the efficiency of mechanisms set in place to exchange ideas between the multiple actors operating in the system (Arnold & Bell, 2001). Traditional R&D providers are required to become more client-oriented which calls for demand-driven modes of working and establishing linkages with the private sector and society as a whole (Klerkx & Leeuwis, 2007). Guidelines and tools to diagnose linkages and capacity to innovate are presented by Hall and colleagues (2006). With innovation systems thinking applied to agricultural research, rather than research the innovation intermediaries take central stage as match makers between suppliers and users of technologies. Innovation predominantly derives from 'working with and reworking the stock of knowledge' (Arnold & Bell, 2001: 288), not necessarily the creation of new knowledge, and from brokering networks, learning alliances or innovation platforms (Adolph, 2005).

Research centres, such as those belonging to the Consultative Group on International Agricultural

Table 3 Farmers' practices to reduce nuisance of *Oecophylla* during harvest, Guinea, 2006 ($n = 100$)

Farmers' practice	*% of farmers*
Don't do anything	38
Apply ash to parts of body	20
Apply petrol to parts of body	19
Use a long picking pole	11
Clean area around trees before harvest	6
Wear boots and gloves	4
Use leaves and twigs to sweep away ants	2

Research (CGIAR) that emerged about 40 years ago to address key production constraints, operate within quickly changing natural, economic and societal environments. To what extent CGIAR centres are able to adapt their R&D priorities and partnerships to new needs will determine their future relevance. However, the current membership of the CGIAR Science Council, lacking user representatives, means that the legitimacy of the priority setting and strategic direction can be challenged (Scoones *et al.*, 2008a).

In 2007, the World Bank started to attribute funds to individual CGIAR centres, placing more weight on outcomes than on outputs. This incentive orients the centres towards innovation systems thinking, whereby partnerships, uptake and impact have to be thought through right from the beginning of the innovation process rather than at the end (Van Mele, 2007). Centres have to rethink and renegotiate their role within innovation trajectories. To transform Third World agriculture the national systems of innovation need to be integrated with outside knowledge sources through well-organized knowledge markets (Clark, 2002). So, are CGIAR centres to become process-oriented or content-oriented agricultural R&D agents, or a combination of both? The CGIAR's intended beneficiaries are poor people in developing countries. Considering the disintegration of national extension systems and the increasing number of (often small-scale) service providers, a new niche for the CGIAR as knowledge and network broker may have emerged.

To increase the relevance and effectiveness of R&D, public–private partnerships are increasingly being promoted by advocates of innovation systems (Hall *et al.*, 2001; World Bank, 2007). SIPEF headquarters showed little interest in the use and promotion of weaver ants. When the density of private sector actors is extremely low, the scope for pro-poor, sustainable market development is limited. Public–private partnerships contribute little to sustainable agriculture in developing countries where the agrochemical industry has a quasi monopoly in cashing in on the growing horticultural market. National agricultural scientists, short of research funds, may be more inclined to team up with pesticide companies to test their products in farmers' fields. Years of superficial interactions and on-farm research led scientists to believe that weaver ants were pests rather than beneficial insects, because both scientists and farmers lacked ecological knowledge. Partnerships and participatory approaches are no guarantee for pro-poor, sustainable development when farmers' explicit demands are naïve, or when researchers have only a superficial grasp of the farmers' reality, or when research funding mechanisms affect scientists' impartiality. Current trends indicate that funding streams will increasingly be conditioned by private sector involvement. Especially in countries where the private sector and civil society organizations are weak, such 'innovative' funding arrangements will create limited opportunities to work towards sustainable development goals and pro-poor impact. The warning by Robert Tripp (1993: 2003–2004) still holds that 'there is a real danger that both external donors and national governments will use the new alternatives (private sector and NGOs) as an excuse to abandon rather than to reshape the public sector contribution to agricultural development'.

Ecological literacy

Apart from the establishment of new varieties, it is argued that limited impact of research by the CGIAR is due to the location specificity of most technologies. Scaling-up of sustainable technologies requires building effective networks, but also developing ecological literacy (World Bank, 2008).

Farmers and scientists must learn to read from the same page. Few scientists have been involved in developing pest management technologies for smallholder fruit farmers with a focus on endemic predatory ants (Van Mele, 2008). Even well-trained scientists may not be aware of the potential of certain very abundant endemic natural enemies. As mentioned earlier, the director general of the national research institute was unaware and pleasantly surprised to hear about the role of weaver ants in protecting tree crops. In some cases, scientists were aware, but did not express their knowledge for various reasons. When I gave a presentation on the benefits of weaver ants during a workshop in Tanzania in August 2007, staff from the Ministry of Agriculture, Food and Cooperatives were surprised that no one had ever informed them about this readily available solution to the national fruit fly problem. This was especially striking because one of their senior scientists had done his PhD on *Oecophylla* in pest control. R&D prioritization and developing demand-led research is an iterative process that benefits from long-term engagement, but this may not always be enough. Researchers, growers, field workers and harvesters hold different sets of ecological knowledge and can learn from each other (Van Mele *et al.*, 2008). Their knowledge needs to be repackaged and communicated to their peers, as well as to a non-technical audience, such as policymakers and the civil society, who increasingly play an active role in R&D priority setting.

Apart from emphasizing the need to build ecological literacy among researchers and farmers, this paper also showed the importance of mindsets. Innovation intermediaries involved in R&D priority setting exercises (scientists, consultants, cooperatives, research user groups or others) need to appreciate that farmers' explicit demand for pesticides stems from the problem of ants during harvest and from their ignorance of the benefits of weaver ants in pest control. In a review paper describing the needs of tree crop growers, Williamson (2002) reiterates the need to build ecological literacy along the value chain and to enhance institutional and marketing innovations. Although embedded in the CGIAR System Priorities (CGIAR, 2005), the building of ecological literacy within innovation systems needs more explicit articulation for research to optimally contribute to sustainable development objectives.

While linkages within the national agricultural research systems have improved considerably, a major imbalance between research institutions, universities, farmers' organizations, NGOs and other stakeholders still exists in many African countries (Beye, 2002). Apart from the nature and the quality of the linkages, outcomes of R&D priority setting for natural resource management largely depend on the ecological literacy of scientists, farmers and innovation intermediaries. Voting exercises to bring in farmers' voices in priority setting appear to work well for selecting varieties, but may be harder for technologies that rely on more tacit knowledge, such as soil fertility or pest management (Ayenor *et al.*, 2004; Pingali *et al.*, 2001). Farmers will never vote for the use of weaver ants to control fruit flies, if they do not know about its importance.

Focus on appropriate technologies

Responding to farmers' explicit demands does not always lead to sustainable agricultural practices. Treating pests in 10 m high trees with insecticides – as frequently requested by farmers – is expensive, ineffective and leads to human and environmental problems. With few exceptions, the bulk of scientists researching fruit fly control options at international research stations have focused mainly on high technologies, such as parasitoids, baits and fruit fly traps that are unlikely to become available to the majority of resource-poor African farmers (Van Mele *et al.*, 2007). A convergence between natural and social sciences is needed to better capture farmers' implicit demands *and* to make researchers respond to them (Ayenor *et al.*, 2004). Instead of comfortably sticking to high technologies, researchers should attempt to find solutions that are cheap and accessible to the poor.

Building socio-technological literacy within the agricultural innovation system enhances the poverty relevance and potential uptake of research results. Innovation intermediaries who have good ecological and socio-technological literacy levels are more likely to come up with a clear vision, strategies and research priorities than those who lack these capacities. In turn, strategic research on technologies that are appropriate to the poor can have considerable potential to improve *both* efficiency and poverty alleviation effects of research over wide areas (Byerlee, 2000). Following research by Hedström in the late 1980s and by Epsky and colleagues throughout the 1990s, a breakthrough was made in developing cost-free and alternative fruit fly baits and traps based on urine and chicken faeces (Piñero *et al.*, 2003). Our research in Africa indicated that farmers explicitly demanded insecticides, but their implicit demand was for cheap fruit fly control and for management of ants during harvest. This only became apparent as scientists and farmers taught each other to read the local farm-and-ant ecology.

New fundamental research questions arise

More in-depth interactions with farmers and an open mind to actual problems versus perceived solutions may equally inform fundamental research. To address the nuisance of the highly effective weaver ant, apart from local knowledge and practices, the knowledge of more fundamental myrmecologists could also be mobilized. Studies that reveal the mechanical and neural functioning of the ants' adhesive pads (Federle *et al.*, 2004) may lead to new insights into reducing nuisance from weaver ants during farm operations. The revealing of mechanisms to reduce the functioning of the ants' adhesive pads may lead to a new technological breakthrough that could radically change the perception of the scientific and rural communities who often classify *Oecophylla* as a pest. Various farmers across Africa and Asia have already developed technologies to reduce the ants' nuisance that may guide natural scientists towards new experiments (Van Mele *et al.*, 2008).

In-depth local knowledge may have uncanny similarities to scientific finding. For example, ants not only protect plants from herbivores and other insect pests, but they also play a direct role in fertilizing the plants. Recently, researchers found that within six days, up to 25% of the nitrogen ingested by *Pheidole* ants was incorporated by the plants (Fischer *et al.*, 2003). Interestingly, when entomologists in Vietnam first interviewed citrus farmers on *Oecophylla* in 1992, the majority stated the benefit of the weaver ant to be improved fruit quality rather than pest management (Barzman *et al.*, 1996). Farmers said the effect was comparable to fertilizer use and was due to the 'ant urine' deposited directly on the fruit. Scientific validation confirmed enhanced juiciness, external shine and overall appeal. Women organized in picking teams to harvest mangoes in Benin equally target orchards with weaver ants for reasons of improved quality. As they buy the harvested fruit on the spot and sell it at the local market, quality matters to them (Sinzogan *et al.*, 2008). Weaver ants deposit drops of a complex of exocrine compounds (Hölldobler & Wilson, 2000) that may have similar effects to foliar fertilizers. The effect of weaver ants on tree crop fertilization would be a good area for strategic research, considering that the bulk of African farmers do not have access to mineral fertilizers.

Learning and communication

Lack of appropriate market and institutional incentives can lead to the rapid erosion of sustainable agricultural knowledge and technologies. Ecological knowledge also declines with economic growth when farmers start to perceive traditional practices as old-fashioned. When Vietnam moved towards an open market economy in the 1990s, continued pressure from the pesticide industry and with only one national scientist promoting the use of weaver ants, fruit farmers gradually abandoned their traditional practices of conservation biological control whereas newcomer fruit farmers never learnt about these sustainable practices (Van Mele & Cuc, 2000). Capacity building of multiple Vietnamese institutes and farmer associations, media campaigns, emerging markets for organic produce, and an increased interest from donors and national policymakers in sustainable fruit production has shifted this trend (Van Mele, 2008). Environmental education through farmer field schools (FFS) or mass media can be equally effective in changing farmers' pesticide use behaviour and appreciation of natural enemies (Price, 2001), especially if proper attention is paid to the process of merging researchers' and farmers' knowledge (Van Mele & Chien, 2004). This resonates with the literature on conservation education. According to Bride (2006), conservation biologists should take every opportunity to educate people about basic principles of conservation, rather than just 'informing' them.

People can improve their understanding of biodiversity and agro-ecological relationships at the same time as they develop new social rules, norms and institutions. This process of social learning helps new ideas to spread and can lead to positive biodiversity outcomes over large areas (Pretty & Smith, 2004). New ideas spread more rapidly where there is high social capital. In 2007 and 2008, associations of organic fruit growers, such as the Coastal Out-growers Association who produce organic citrus in Ghana or Burkinature and Fruiteq who produce organic mango in Burkina Faso, were prime targets to build capacities on weaver ant husbandry in Africa. To build ecological literacy among the broader society, also mass media campaigns have been launched. Under the auspices of the Inland Valley Consortium (IVC), hosted by the Africa Rice Center (WARDA) in Benin, a set of rural radio programmes with women fruit pickers, scientists and experienced growers was developed to be shared with Farm Radio International, which reaches out to over 300 rural radios across Africa. Educating a broad societal base on ecological issues ought to positively influence R&D priority setting towards sustainable development.

Conclusion

The introduction of farmer participatory approaches over the past decades has to some extent improved the relevance and subsequent uptake of research results. While R&D prioritization ought to open up to involve more actors, including the private sector, policymakers and civil society, building ecological and socio-technological literacy within the innovation system is urgent. At the same time, multi-stakeholder priority setting strategies will need to be looked at through an ecological and a socio-technological lens, especially for agricultural development to be sustainable and socially inclusive.

Acknowledgements

We thank the staff of IRAG who were involved in the survey, and are indebted to all the growers and fruit pickers involved in the research. The Conservation, Food and Health Foundation sponsored this work. The study was undertaken through the Inland Valley Consortium (IVC), hosted by the Africa Rice Center (WARDA). IVC aims at developing appropriate technologies to help farmers to profitably increase productivity of inland valleys, while conserving the environment and biodiversity.

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