A methodology for tracking the 'fate' of technological interventions in agriculture

Abstract. The primary focus of agricultural research and extension in eastern Africa is technology generation and dissemination. Despite prior critiques of the shortcomings of this approach, the consequences of such activities continue to be measured through the number of technologies developed and introduced into the supply chain. At best, impact is assessed by the total numbers of adopters, and by the household and system factors influencing adoption. While the diffusion research tradition has made substantive advances in recent decades, attention to what happens to technologies after adaptive on-farm research trials continues to be limited in practice. While a host of newer approaches designed to correct for past shortcomings in diffusion research is now available, integrative methodologies that capitalize upon the strengths of these different traditions are sorely needed. This article presents a more encompassing methodology for tracking the fate of technological interventions, illustrating the potential applications of findings for enhancing the positive impact of agricultural research and extension in the region.

Key words: Agriculture, Eastern Africa, Farming system, Diffusion of Innovations, Technology adoption

Introduction

The primary focus of agricultural research and extension in eastern Africa is on technology generation and dissemination. Despite prior critiques of the shortcomings of the agricultural research and extension complex (deGrassi and Rosset, 2003; Havens and Finn, 1974; Hightower, 1972; Shiva, 1991), the consequences of related activities are given limited attention. While farming systems approaches have enabled improved "fits" of technologies into complex farming systems (Eklund, 1983; Hagmann, 1999) and adoption studies have provided theoretical and methodological frameworks for understanding patterns and impacts of technology innovation (Rogers, 2003), throughout much of the world attention to what happens to technologies after adaptive on-farm research trials is often given only to numbers and characteristics of adopters (Nkonya et al., 1997; Wozniak, 1987). Impact is measured through the number of technologies developed and introduced into the supply chain, or at best through assessment of total numbers of adopters and the factors influencing adoption. This reflects the pro-innovation bias of change agents who often commission these studies (Rogers, 2003) and the strong influence of an earlier era of adoption research (Ryan and Gross, 1943).

Experience demonstrates that a host of factors will influence the success and rates of technology adoption. These include farmer or household characteristics (wealth, age, gender, labor availability), farming system characteristics (land and livestock holdings, slope, access to irrigation), resource access (social networks, planting material, information), properties of the technology itself (how quickly it generates returns, required capital and labor investments) and farmer access to social networks (Adamo, 2001; Bunch, 1999; Negi, 1994; Perz, 2003; Shaxson and Bentley, 1991). If technological innovation is seen as a discrete step (introducing new technologies) rather than a process (from problem definition to technology targeting, testing, monitoring, troubleshooting and dissemination or discontinuation), many of these patterns and lessons will be lost. Substantial risks may also be introduced into the system through socio-economic gap-widening or decreased agroecosystem resilience. Furthermore, the opportunity for a more adaptive management approach to managing technology innovations and impacts will be lost (see Douthwaite, 2002).

Technology 'tracking' is important for several reasons. First, increasing recognition that blanket recommendations which fail to take into account household and farming system characteristics do not work (Chambers et al., 1987; Scoones and Thompson, 1994), demonstrates the importance of understanding the specific social and farming system "niches" where technologies most easily fit. We define niche in this context as the suite of social and farming system variables – including gender (and gendered activity domains and livelihood constraints), household labor, resource endowments (land, irrigation, livestock) and the like – that facilitate or inhibit easy integration of an innovation into a farming system. Second, technology tracking enables the identification of major bottlenecks to technology access and adoption by different social groups, which are in turn critical leverage points for enabling more widespread social benefits from technological innovation. Third, it enables the identification of technological "re-invention" or adaptations – departures from recommended practice – that enable technologies to fit more easily into local farming systems (Bentley, 1990; Reij and Waters-Bayer, 2001). Fourth, such studies can increase the efficiency of research and development (R&D) interventions by identifying critical leverage points for livelihood and farming system improvements and social networks that either enhance or hinder widespread access to benefits in the absence of external mediation (Adamo, 2001). Finally, positive *and negative* impacts of technological innovation on livelihood and the environment and the type of farmers benefiting from interventions can be tracked (see de Grassi and Rosset, 2003; Haugerud and Collinson, 1990; Shiva, 1991), adding a much-needed ethical dimension to technological interventions (Cooley, 1995).

Following a brief background in which existing approaches for tracking the fate of agricultural technologies and the need for an integrated approach are illustrated, a methodology is outlined for tracking the fate of technological interventions. The methodology emphasizes technology "spillover" – the spontaneous, farmer-to-farmer spread of technologies in the absence of outside mediation – which gives greater insights into adoption and impact than research- or extension-mediated diffusion. The paper concludes by illustrating some of the findings of such an approach, and implications for improving the targeting and impact of agricultural research and extension programmes.

Background

A history of diffusion research

Early approaches to researching the diffusion of innovations emerged from the fields of anthropology, geography, sociology, health, marketing and communications, but consolidated into a single research tradition in the 1960s (Rogers, 2003). While these diverse traditions contributed to a rich body of literature on how the characteristics of adopters, innovations, social networks and systems, and opinion leaders influence the adoption and "re-invention" of innovations, an early study by Ryan and Gross (1943), "more than any other study, influenced the methodology, theoretical framework, and interpretations of later students in the rural sociology tradition, and in other research traditions" (Rogers 2003:55). This is even more so in developing nations. Here, interest in studying the diffusion of innovations has been strongest in the agricultural sector, which was strongly influenced in the 1960s by a systematic attempt to export the land-grant university and agricultural extension model to developing nations.

The study by Ryan and Gross (1943) used a retrospective survey method to model the diffusion of hybrid corn in Iowa. This study sought to correlate innovativeness (the time of adoption) with a number of variables such as the adopter's age, education, farm size, income and access to diverse information sources. The methods used by Ryan and Gross and other early diffusion researchers have since been subject to a great deal of critique, and a host of innovations have been introduced into diffusion methodologies themselves (Table 1). Critiques of early approaches include its pro-adoption bias, which leads to an over-emphasis on externally-introduced and fixed innovations (failing to capture re-invention processes taking place after introduction), one-way communication from service providers to end users, and on adoption relative to impact or rejection of introduced innovations. A second critique is methodological. The retrospective one-off survey method, in which adoption levels are assessed at a single point in time at the level of individual adopters and technologies, is ill-suited for understanding broader diffusion networks and processes, cause and effect relationships, the interdependencies in the uptake of different innovations, or the role of the broader system (change agents, institutional and political-economic context) in enabling or hindering adoption (Katz et al., 1963; Mohr, 1966; Rogers, 2003).

→ **Table 1.** Critiques of Early Diffusion Studies and Subsequent Methodological Advances

While a host of new studies have expanded upon and improved early diffusion research methods (Table 1), these approaches have had little effect on the tracking of agricultural innovations in developing nations. Diffusion studies proliferated in Africa, Asia and Latin America in the 1960s and early 1970s, during a time when North-South technical exchanges were taking off and technological optimism formed the backbone of the development paradigm (Rogers, 2003). As a result, correlational analyses from retrospective surveys in the Ryan and Gross tradition are still the norm (Franzel et al., 2002; Nkonya et al., 1997; Semgalawe, 1998).

The case for an integrated approach for tracking the fate of agricultural innovations

Most of the past critiques leveraged against diffusion studies in diverse disciplines are highly relevant to current practice within the agricultural sector today throughout much of the developing world. Some of the most relevant critiques reflect the need to:

- *Move from a focus on adoption to a focus on socio-economic and environmental impact.* The ultimate goal of agricultural R&D should not be technology adoption, but rather positive outcomes on livelihood and sustainability. A growing body of literature highlights negative social and biophysical impacts of technological innovation, including impacts on patterns of resource access and exclusion and impacts of system simplification on agroecosystem resilience (Altieri, 2002; deGrassi and Rosset, 2003; Sharp, 1952; Shiva, 1991; Swanson, 2002). It also highlights approaches for identifying and managing these impacts (Douthwaite et al., 2001, 2002). These approaches reflect a broader trend in development and conservation practice toward adaptive management and social learning approaches (Castellanet and Jordan, 2002; Morgan and Ramirez, 1983; Röling and Wagemakers, 2000), and bring a much-needed ethical dimension into technology generation and dissemination.

- *Shift from positivist to constructivist modes of inquiry.* The conventional scientific paradigm is guided by a realist-positivist epistemology, which holds that reality exists independent of the human observer, and scientific research is the means to acquire true knowledge about the nature of that reality (Röling, 1996). Agricultural science is deeply rooted within this paradigm. Constructivist inquiry is based upon the premise that the world has multiple, socially constructed realities (Chambers et al., 1992), and recognizes the need to integrate perspectives from diverse actors when trying to gain an understanding of complex systems. By integrating the observations of different actors within a system, constructivist inquiry also minimizes the 'individual blame' bias (Rogers, 2003) in determining cause-and-effect.
- *Move away from the source bias (unidirectional transfer of 'static' innovations) to understanding the adaptive logic of re-invention*. The conventional concept of technologies (static and research-driven) has obscured the importance of continuous adjustment or 're-invention' of technologies in adapting them to existing farming systems in a way that does not enhance risk or place excessive demands on limited on-farm resources (capital, land, labor, water, nutrient resources). Methods to capture processes and motives for re-invention must enter standard methodological toolkits for studying diffusion. Some authors point out that a program can only sustain positive impacts if constant technological innovation and adaptive management of smallholder farming systems are encouraged (Bunch, 1999). Faster recognition of this by NGOs than by government or UN-funded institutions is in large part responsible for their greater success in overcoming adoption barriers for more complex, conservation-oriented technologies (Ibid).
- *Embrace a more nuanced understanding of social networks and benefits*. An understanding of the role of social networks in the dissemination of innovations is necessary to understand how program benefits can reach more farmers with minimal outside investments (Adamo, 2001), and to understand and minimize the tendency for innovations to widen the socioeconomic gaps within a system through benefits capture by local elites (Munk Ravnborg and Ashby, 1996; Brosius, Tsing and Zerner, 1998; Havens and Flinn, 1974). Prior research has highlighted the prominent role of interpersonal kinship, friendship and patronage ties relative to formal avenues of information transfer (Adamo, 2001; Armonia, 1996; Hossain, 1998), as well as the potential for correcting for gap-widening effects through more explicit social targeting of innovations (Röling et al., 1976).

Despite the relevance of these perspectives to agricultural research and development, they remain marginal in practice throughout eastern Africa. If diffusion studies are carried out at all within agricultural research and extension systems, the emphasis continues to be on adoption (obscuring processes of re-invention, rejection and impact), on the individual level of analysis (obscuring system or network effects on adoption), and on quantitative survey techniques (with tenuous assumptions on causality and links to alternative frames of reference). Yet the challenges of bringing the many innovations in diffusion research to bear on professional practice in agriculture are daunting given the host of objectives and methodological approaches characterizing these studies. This article seeks to integrate many of the past advances in diffusion research into a single series of steps for tracking the fate of the most common intervention in agricultural R&D: the introduction of new agricultural technologies.

Program context

This research was conducted under the rubric of the African Highlands Initiative (AHI), an Ecoregional Program of the Consultative Group for International Agricultural Research (CGIAR) and the Association for Strengthening Agricultural Research in East and Central Africa (ASARECA). The mandate of AHI is to improve farming livelihoods in densely settled, highly degraded areas of the eastern African highlands, through the development, testing and institutionalization of new methods and approaches to agricultural research and development. The program's human resources include a small, interdisciplinary regional research team and interdisciplinary site teams composed of staff from National Agricultural Research and Extension Systems in each country. Benchmark sites in the highlands of Ethiopia, Kenya, Tanzania and Uganda serve as testing grounds for the formulation and testing of new approaches. This research was carried out in one of these benchmark sites, located in Lushoto District, in the East Usambara Mountains of Tanzania.

New approaches to research and development in AHI benchmark sites are intended for eventual adoption by agricultural research and extension systems throughout the region, whose mandate is predominantly one of agricultural technology development and dissemination. They are formulated through a social and experiential learning approach as site and regional staff come together to plan, field-test and evaluate approaches in the field. Given this action research orientation to methodology development, both the methodology and the findings presented in this paper constitute "research results" – the methods an outcome of an action research process (where methods testing is done through an iterative process of planning, testing and modification) and the findings a product of empirical research (application of the methodology).

From 1997 to 2002, AHI tested a participatory process for problem identification and adaptive research on-farm, where new technologies were targeted in response to locally identified problems. Given the large range of problems affecting farmers – cutting across crop, soil and livestock components – technologies were introduced in clusters. These included crop germplasm (for staple and high-value vegetable crops), soil management practices (soil conservation structures, integrated soil fertility management measures) and livestock innovations (housing, feed and sanitation). In some cases technology clustering was intentional and planned, as with the combination of soil fertility management practices and crop germplasm or with the integration of soil and water conservation and livestock (manure usage during terrace construction, terrace stabilization with fodder). In cases where clustering was not intentional, this simultaneous introduction of new technologies nevertheless created an opportunity for farmers to creatively combine technologies in their farms. While the methodology described below may be used to track the fate of a single technology once introduced into a system, it is more illustrative of how properties of the technology, farming system and social networks influence diffusion when compared across different types of technologies.

Methodology

Objectives

An integrated methodology for tracking the fate of technological interventions must stem directly from an integrated set of objectives:

General Objective: To gain insight into the spontaneous spread and adoption of technologies, thereby enabling the design of strategies to enhance the positive impacts of technology generation and dissemination.

Specific Objectives:

a) To understand the primary pros, cons and adoption barriers of each technology,

b) To understand the characteristics of households and farming systems where the technology is spontaneously adopted,

c) To identify forms of, and motivations for, social and biophysical innovation (“re-invention”),

d) To characterize social networks through which technologies flow in the absence of outside mediation, and

e) To identify the socio-economic and environmental impacts of introduced technologies.

Research questions

The following research questions were designed to operationalize the above objectives:

- What are the primary pros, cons and adoption barriers of each technology?
- What are the social and farming system ‘uptake niches’ of different technologies?
- What farmer innovations (re-inventions) were made to introduced technologies?
- What is the nature of social networks through which technologies flow spontaneously?
- Did introduced or modified technologies have any impact on livelihood or social dynamics?
- Did introduced or modified technologies have any impact on agroecosystem resilience?

Findings to these questions will enable the design of more informed and responsible interventions in the agricultural sector. Pros, cons and adoption barriers identified in pilot sites enable technologies to be improved upon to increase their accessibility to a wide range of farmers, as well as the more strategic design of interventions (to increase access to germplasm vs. information, for example). Identification of social and biophysical uptake niches is needed for the design of technologies targeted to different types of farmers and farming systems, to minimize the gap-widening effects of technology introductions (Rogers, 2003). Identification of re-invention processes and their underlying motives enables R&D actors to gain a deeper understanding of how technologies must change to adapt to local farming systems, and the inclusion of new messages derived from farmer innovations within planned dissemination strategies. Understanding the social networks through which technologies flow in the absence of outside interventions gives an understanding of processes of social inclusion and exclusion operating within the social system, and points to possible entry points for fostering more equitable benefits from technology dissemination. Finally, illuminating the positive and negative consequences of diffusion is needed so these can be managed explicitly to enhance the positive impacts of technology dissemination on livelihoods, equity and agroecosystem resilience.

Methodological steps

The methodology for addressing each of the proposed research questions is broken down into four basic steps that correspond with the need to integrate constructivist inquiry into formal survey methods for tracking technologies. These include:

Step 1: Constructivist inquiry to identify basic patterns in uptake. While personal experience and familiarity with the literature gives researchers knowledge of important factors influencing the adoption of technologies falling within their area of expertise, farming systems and farmer decision-making processes are extremely complex. This serves as an absolute constraint on what researchers themselves can know *a priori* about potential variables influencing uptake. It is essential, therefore, that surveys designed to track technologies begin with a broadly participatory assessment of patterns of uptake as observed by farmers themselves. Focus group discussions with diverse groups (adopting and non-adopting farmers, primary and secondary adopters, or gender- and wealth-based groupings) can be used for this purpose. Ideally, focus group discussions with new groups of farmers should be repeated until significant overlap is found in the answers given and it can therefore be assumed that a comprehensive understanding of patterns of technology uptake and re-invention (as observed by farmers) has been attained.

Step 2: Tracking surveys with on-farm interviews. Variables identified by farmers as influencing adoption (from Step 1) are then compiled along with variables intuited by researchers from the literature or direct observation, and integrated into a formal tracking survey that is made more robust through local "ground-truthing"[1] of the relevant variables to be tracked. This survey is applied in the form of a structured household interview to capture the household and farming system characteristics of a large number of adopters, a standard step in more econometric analyses of diffusion. By conducting these formal surveys on-farm, a further opportunity is provided to capture information that lends itself to more qualitative case study methods (re-invention, social and biophysical spin-offs).

Different sampling procedures can be used for these tracking surveys, depending on the ultimate objective. Standard random sampling techniques may be used if the interest is to conduct a rigorous econometric analysis of adoption variables. Alternatively, a form of snowball sampling may be used if the interest is to understand social networks through which technologies diffuse in the absence of outside interventions or how adoption levels and technologies themselves change through successive levels of 'spillover' (Figure 1). The "level of spillover" is defined as the distance (measured in terms of the number of social transactions) the technology has spread from the original farmer involved in adaptive on-farm research. Technology adoption among farmers directly involved with project personnel may have a bias due to motives for adoption that are de-linked from the actual benefits derived from the technology itself (Mowo, pers. observation).[2] It is therefore important to designate such farmers as "L_0" (level zero), indicating that spontaneous sharing of technologies among farmers has not yet occurred. Successive levels of spillover are therefore defined in relation to how many transactions the technology has passed through to be adopted. Farmers adopting from "project farmers" would therefore be designated "L_1" or level one of spillover, and so on.

→ **Figure 1.** Levels of Technology "Spillover" Relative to Project Interventions

Following these spillover pathways, a certain percentage of farmers at each level are interviewed to document household and farming system characteristics, the nature of social networks through which the technology was acquired, and with whom they in turn shared the technology (enabling identification of farmers at the next level of spillover). These structured surveys are combined with more open-ended interviews and farm visits when more detailed information on processes (farmer re-invention, social and environmental impact, technology adoption) is required. It is important that tracking surveys target not only adopting farmers, but also randomly selected non-adopters, therefore allowing emerging patterns of adopters to be compared with the demographic of the community at large (a "control group").

Step 3: Data analysis. The third step involves statistical analysis of data from tracking surveys, and qualitative analysis of data from semi-structured interviews and farm visits. Basic patterns observed for each objective and associated research questions are discerned at this time. The total number of adopters can only be assessed by extrapolating out from the percentage of farmers interviewed at each level,[3] yet care must be taken in interpreting these numbers if farmers have not kept records on technology sharing due to known inaccuracies in recall data (Rogers, 2003). The data are nevertheless useful in understanding relative numbers, such as the percentage of exchanges characterized by kinship ties or the percentage of female adopters.

Step 4: *Focus group discussions to interpret emerging findings.* Step 3, data analysis and interpretation by researchers themselves, is generally the final step of econometric analyses. However, a number of assumptions must be made about the reasons for observed patterns in the absence of additional "ground truthing" to explicitly integrate the interpretations of farmers or other actors in the system. Pattern interpretation by different actors can be useful for several reasons. First, patterns that would otherwise be difficult to observe are fed back to farmers or others, giving them a chance to contribute further in interpreting their own behavioral patterns. It also gives a more complete and nuanced view of farmer behavior by integrating local logic with scientific logic in interpreting observed patterns.

Different research questions are best answered through different forms of data. The sequencing of qualitative, constructivist steps with more quantitative surveys therefore provides an opportunity to match research questions with the most appropriate methodological steps (Table 2). While integration of recent advances in diffusion research into a single methodology has the obvious disadvantage of minimizing the detail of lessons that might be learned from more targeted methodologies, the advantages are also clear. In addition to providing a manageable methodology for research and extension systems to track (and to take responsibility for) the 'fate' of their interventions, the methodology offers clear improvements over the model currently in use in eastern Africa across a host of evaluation criteria (Table 3).

→ **Table 2.** Methods Targeted by each Research Question

→ **Table 3**. Aspects of the Proposed Methodology as a Function of Past Critiques

Results and applications

As the objective of this paper is to present a methodology as much as empirical research results, results are chosen selectively to illustrate different aspects of the method itself.

Case No. 1: 'Ground truthing' surveys in farmers' observations

Focus group discussions carried out with AHI and non-AHI farmers pointed to several important variables influencing the adoption of technologies introduced by the project. The following variables were identified as influencing adoption of soil conservation technologies, and integrated as new variables in the tracking survey (variables in bold font in Tables 5 and 6): a) Limited access to technical assistance due to limited number of village paraprofessionals; b) Limited access to organic nutrient resources for the implementation of bench terraces, required to off-set the decline in soil fertility resulting from topsoil disturbance; c) Labor requirements, including total numbers of household members and their age; and d) Presence of permanent crops, hindering the ability to implement physical structures.

In addition to these variables, scientists had identified through their own observations a number of additional variables likely to influence the adoption of soil and water conservation technologies in particular (indicated in grey font in Table 6). These included: a) Soil quality prior to implementing soil conservation measures, presumably influencing a farmer's motivation for conserving his or her fields; b) Access to irrigation water, assuming that farmers are more likely to invest in activities with longer-term returns (natural capital) in areas where cash crops are cultivated; and c) Landscape position – including the proximity of conserved plots to households (which influences the ability to transport manure to terraces and keep watch over cash crops) and water resources.

Impacts stemming from the adoption of soil conservation practices were also identified through focus group discussions with adopting farmers and from researchers, and integrated into the tracking survey. Those identified by farmers include increased crop vigor, soil fertility and soil water holding capacity (indicated in bold font in table 6). Researchers then wanted to monitor the influence of these locally identified variables on related factors, including income (presumably enhanced through increased crop vigor and soil fertility) and incidence of weeds (presumably increased through soil fertility improvements) (indicated in grey font in Table 6). They also wished to know the total area under which the new technologies have been applied, as an additional indicator for measuring impact.

A generic survey form integrating standard farming system and household variables likely to be important irrespective of the particular technology being tracked or other contextual factors related to the region where work is being carried out is shown in Table 5. Additional variables particular to soil conservation technologies and corresponding to farmer-identified adoption barriers (Table 4) were added to the generic survey, thereby "ground-truthing" the tracking survey in the properties of the specific technology being tracked and in farmer-identified variables. These additional variables are shown in Table 6. By systematically tracking variables of interest to farmers as well as researchers, all actors in the system (research, extension, farmers) can gain awareness more systematically on the impacts of interventions as viewed by other actors in the system.

→ **Table 4.** Adoption Barriers Identified through Focus Group Discussions

→ **Table 5.** Survey Instrument for Technology Tracking (Generic)

→ **Table 6**. 'Ground-Truthed' Survey Instrument for Tracking Soil Conservation Technologies

Case No. 2: Tracking adoption bottlenecks

The second case study illustrates the importance of understanding patterns of adoption throughout successive levels of spillover. Of diverse technologies introduced to Lushoto by AHI, one of the most popular among diverse types of farming households was a high-yielding variety of banana coupled with improved agronomic practices for planting and managing the crop. Despite this popularity, the observed spillover from L_1 to L_2 farmers was just 11% the spillover from L_0 to L_1 three years after introduction (265 adopters at L_1, compared to 30 at L_2) (Table 7). This contrasts with 34% for tomato seed and 13% for soil and water conservation technologies, the latter being notorious for slow adoption rates despite its relative success in the pilot site. Additionally, despite the broad social and farming system niches and appeal of banana, the maximum level of spillover was two exchanges (level 2). Additionally, unlike tomato, most banana and soil and water conservation technologies (both materials and assistance) were exchanged among farmers free of charge.

In tracking these technologies through successive levels of spillover and discussing patterns with farmers in focus group discussions, it was determined that the only reason for slow adoption was the limited availability of germplasm. This occurred because outside intervention in the technology's diffusion stopped after the adaptive research phase and the propagation rate of suckers (for farmer to farmer 'spillover') is slower than for other crops. In tracking the social relationships characterizing technology sharing, it was found that banana was the technology with the highest proportion of exchanges characterized by family ties, further suggesting that it is a scarce commodity for which sharing is done discriminately. The implications of these findings for reaching more farmers are clear: since social and environmental impacts are positive yet benefits inequitably distributed, methods for multiplying and ensuring more equitable access to banana suckers are needed. Yet foresight in the eventual consequences of rapid dissemination (i.e. the potential for increased pests and disease) is also needed so that awareness on the need for in-situ preservation of local germplasm may be fostered. This genetic diversity is a source of resilience in socio-ecological systems. In providing alternative germplasm that may be better adapted to a wide range of future environmental stresses or providing a rather secure fall-back (given its adaptation to local environmental conditions), this enhances the capacity of local communities to respond to unpredictable future conditions.

→ **Table 7.** Adoption Patterns for Popular AHI Technologies

Case No. 3: Tracking social innovations

Semi-structured interviews were utilized to identify technological innovations, including changes in the technology itself, changes in the farming system to accommodate the technology, and social innovations that enhanced technology adoption. It is the latter that was selected as the subject of this case study, due to the limited treatment of such innovations in the literature.

During the tracking survey and on-farm interviews, a number of social innovations were identified that enabled technology adoption and improved livelihood. For the implementation of bench terraces, one of the most common complaints was the high demand placed on household labor and organic nutrient resources (Table 4). Farmers in Kwalei village, Lushoto, were found to have adapted the traditional labor-sharing practice of *Ngemo* to assist one another in the construction of bench terraces. Another important social innovation identified during household interviews emerged from the introduction of a variety of tomato with high market value, coupled with optimal use of manure and urea. Youth with little access to land had made an agreement with an elder landowner with ample access to valley bottoms (ideal for tomato) but limited labor and organic nutrient resources. While the cost of inputs and all proceeds were shared equally, the labor-intensive work (including transporting farmyard manure and the preparation of stakes to support the tomato plants) is done by the youth. Such synergies were beneficial to all involved, complementing one another regarding their respective resource endowments (labor vs. land). This also enabled us to identify a potentially negative environmental side-effect of this social innovation, namely the transfer of a limited resource (organic nutrient resources) from some households and landscape niches to others (see below). While this may simply be a way of making more economically and mutually beneficial use of existing resources, it introduces a risk into the system by restricting use options of niches from which these resources were diverted.

Other innovations included synergies between technologies and resource investments, for example combining high-value crops with investments in bench terrace construction so that organic nutrient resources are utilized to ensure economic returns while also enhancing soil fertility long-term. A social innovation associated with this practice included joint hiring of a lorry to bring manure to the village for use in tomatoes and bench terrace fertilization, off-setting the high demands for organic nutrient resources accompanying these new technologies. Such innovations need to be captured by research and extension, so as to incorporate some of the principles (social synergies, off-setting negative spin-offs from new organic nutrient resource flows) into dissemination strategies.

Case No. 4: Tracking social networks through which technologies flow spontaneously

Tracing technologies out through different levels of spillover enable the identification of social networks through which technologies flow in the absence of external mediation. Table 7 summarizes social relationships characterizing technology spillover. On average, no difference was found in the tendency to share with kin and non-kin. When findings are disaggregated by technology, however, there is a stronger bias toward kin for the more economically important crops (banana, tomato) relative to the more complex natural resource management technologies, whose benefits are only seen medium-term. More strikingly, while an initial attempt was made by project personnel to enhance gender equity by working equally with men and women in adaptive research, 95% of exchanges were oriented toward male farmers by the next level of spillover (L1). For cash crops, exchanges with women were negligible. These sharp differences stem not only from culturally-prescribed domains of activity, but from information exchanges characterizing patrilocal societies. These data illustrate the need to understand how the social context conditions patterns of inclusion and exclusion of benefits emanating from introduced innovations, and the need to field-test new approaches for minimizing "elite capture" by certain social groups.

Data on types of exchanges (Table 8) further reveal that most exchanges occur at no cost to adopting farmers. This represents a positive trend with regards to maximizing access by resource-poor farmers. However, while knowledge-intensive technologies (SFM, SWC) are never characterized by cash exchanges, 12% of exchanges of economically important crops are. In some cases, financial barriers may exist to technology access for economically important crops. The tendency to place a higher value on technologies that bring in more income and to minimize the value of those that are more knowledge-intensive or for which returns are longer-term, should not be of much concern in terms of technology access as farmers cultivating more cash crops are more likely to be able to afford to pay for them. The effect of differential access to income-generating technologies is, however, an issue due to the tendency for differential adoption to widen the socio-economic gap (Rogers, 2003). It is important also to ensure that prices charged for technologies with broader socio-economic uptake niches (for example, banana) do not hinder access among families with very limited income.

If some groups are found to be excluded due to the cost of technologies or to limited access to social networks through which technology flows, alternative means of propagating germplasm to ensure access by a wide range of families can be put into place. Rules and monitoring for equitable benefits sharing from such activities may also need to be established to minimize the tendency for "elite capture" of outside resources (program benefits, technologies, etc.) among dominant groups.

Case No. 5: Tracking agroecosystem impacts

To research the impact of introduced technologies on the farming system so as to maximize the positive and minimize the negative spin-offs, the potential and perceived farming system impacts identified by farmers and researchers were integrated into the tracking survey. Questions focusing on the reallocation of on-farm resources were also included in more qualitative case studies and semi-structured interviews.

Farmer testimonies indicated that the spin-offs from technology introduction are significant for other components of the farming system. For most technological interventions, these included flows of land, labor and nutrients from other system components (generally from staple to cash crops and hillsides to valley bottoms); positive or negative impacts on soil characteristics (water-holding capacity, fertility, erosion); positive or negative changes in the incidence of pests, disease and weeds; and changes in levels of purchased inputs (Table 9). The increased income from higher yields and increased marketability of tomato stimulated great interest in the crop, leading to positive impacts on soil water holding capacity and soil fertility due to increased use of organic amendments in tomato and fallowing of hillside plots, but negative effects on pests and disease (from decreased crop rotation), increased incidence of weeds (a spin-off of higher soil fertility) and increased use of pesticides. Increased nutrient demands of many high-yielding crop varieties require nutrient diversions from other components of the farming system. In Lushoto, this resulted in increased nutrient flows to cash crops and valley bottoms at the expense of staple crops and hillsides. One farmer noted that the substitution of the traditional tomato-bean rotations with two to three consecutive crops of tomato had a negative effect on soil fertility, placed greater demands on limited supplies of farmyard manure, and decreased the yields of subsequent crops. Another farmer stressed positive spin-offs to other system components, including the ability to restore fertility in hillside plots through fallowing as labor was diverted wholesale to tomato cultivation in valley bottoms.

These data point to the critical importance of monitoring risks to livelihood and agroecosystem resilience stemming from technology dissemination. While agroecological spin-offs may be gradual, the occurrence of some problems such as increased incidence of pests and disease increases along with the popularity of the technology. Such "scale effects" should be well understood and intentionally managed by the agricultural R&D establishment. While contributing to substantial improvements in the income of adopting households (as evidenced in investments in housing, school fees, bicycles and new enterprises, as well as improved food security), overall effects on quality of life at village level are more mixed. While some technologies bring widespread benefits to diverse types of households, some families manage extra income for the benefit of their families, and some agroecosystem impacts will enhance sustainability long-term, alternative scenarios of widening socio-economic gaps, poor investments and negative agroecosystem impacts are also common. This raises a significant challenge for R&D professionals to use a much wider lens and more robust toolkit when selecting interventions and measuring impact.

Discussion and conclusions

This paper illustrates the need for a more rigorous approach to technology tracking in eastern Africa, in which the merits of different diffusion research traditions are integrated into a single approach. The simple, four-step methodology is presented as a means to expand the conventional approach by integrating the observations of different social actors from the outset (for pattern identification and interpretation), inserting locally-identified variables into conventional econometric analyses, and expanding the range of processes observed. The approach integrates the current emphasis on major adoption barriers with research on diverse types of adoption impacts (both positive and negative), social networks through which technology flows in the absence of outsider intervention, and farmer innovations that enable technologies to more easily fit into smallholder farming systems.

So what are the implications of such findings for agricultural research and development efforts? Far from being an academic exercise, findings illustrate the critical importance of knowing the fate of introduced technologies. On the one hand, ground-truthing adoption surveys (both the instrument and the interpretation of findings) in farmer observations is a means for integrating aspects of the technology of greatest salience to farmers into the methodology, thereby enhancing researcher awareness of variables of greatest importance locally. It also ensures that findings are interpreted with respect to the local context by integrating variables of local concern into spillover studies, monitoring related spin-offs and involving farmers in the interpretation of findings. While soil conservation technologies are a poor indication of this, Tables 5 and 6 nevertheless illustrated how farmers contributed to the identification of key causal variables influencing technology adoption and impact indicators of local importance. Identification of the most critical adoption barriers through focus group discussions and surveys (in which the breadth of the adoption niche and speed of spread are each tracked) also enable the more strategic design of interventions for enhancing desired and minimizing undesired impacts. Identification of the slow rate of propagation of banana suckers as a key adoption constraint, for example, led to the targeting of collective multiplication plots through involvement of schools and community-based organizations. Identification of the gender imbalances in technology spillover despite an original emphasis on gender equity by the project (equitable membership in farmer research groups), on the other hand, provides the critical insight that attention to gender equity from the outset does not ensure equitable access to technologies during spontaneous spillover processes. This suggests that new approaches to gender inclusiveness must be tried. Third, the identification of farmer innovations enables dissemination of more relevant practices and the availability of a wider suite of management options, while the identification of social innovations provides insight into the most appropriate organizational strategies for doing so. The synergies established between youth and elders with complementary resources, collective action to import organic nutrient resources into the system, and building upon traditional labor sharing practices are examples of social innovations that should be highlighted along with other aspects of technologies during dissemination.

A final justification, and perhaps most important, is that solving one problem may create another, as illustrated in diversions of farm resources from staple crops and the skewed benefits distributions among men and women. While some earlier methods have also emphasized positive and negative consequences of adoption, this methodology is unique in its robust integration of views (farmers and researchers, adopters and non-adopters), consequences (social and biophysical), and qualitative and quantitative methods (the latter providing, rather unexpectedly, the key insight on gender inequality). Application of such methods as part of standard research practice, and integration of findings into more informed and ethical dissemination processes, is sorely needed in the eastern African region to enhance accountability of the agricultural R&D establishment to the social and agroecological spin-offs of their interventions. This will only happen if improved awareness is coupled with institutional learning processes on successful ways to enhance positive and minimize negative social and environmental impacts of technological innovation. This is where the ethics of science and development comes in – by ensuring that interventions are not only sought by the end users, but accompanied by mechanisms to account for and manage the full range impacts they might bring – and where greater attention needs to be placed in the future.

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[1] We use the term "ground-truthing" to refer to a process through which knowledge or a process of inquiry (including the variables used to track change) is adapted to site-specific conditions, as observed either by farmers or by researchers interacting closely with local communities or the phenomena under observation.

[2] For example, social status derived from interacting with outsiders or a desire to extract other benefits from project personnel.

[3] If only 20% of level one farmers are interviewed, for example, and it was found that they in turn shared technologies with 100 farmers in all, then the number of level two farmers would not be 100 but 500.

Table 1. Critiques of Early Diffusion Studies and Subsequent Methodological Advances (adapted from Rogers, 2003)

Key Attributes	**Critiques of Early Diffusion Studies**	**Innovative Research in the Field**
Characteristics of Adopter Categories	Lack of common semantic ground in assigning terminology; pro-innovation bias of adopter categories.	Classification of adopters (individuals, organizations) by their innovativeness (Rogers, 1958; Mohr, 1969); research on consequences (see below).
Attributes of the Innovation	Failure to capture how properties of the innovation determine patterns of diffusion.	Systematic assessment of the role of '5 attributes' known to affect adoption of all innovations (Fliegel and Kivlin, 1966; Kearns, 1992).
Diffusion Networks	Emphasis on individual adopters has obscured the role of change agents, opinion leaders and social networks in diffusion.	Emphasis on the role of change agents, opinion leaders and broader social structure in diffusion (Carlson, 1965; Coleman et al., 1966; Kelly et al., 1991; Rogers and Kinkaid, 1981).
Re-invention	Failure to view innovations as dynamic and reciprocal; source and pro-innovation biases obscure endogenous innovations.	Research gives equal attention to endogenous innovations or highlights how introduced innovations are re-invented by adopters (Bentley, 1990; Charters and Pellegrin, 1972).
Level of Analysis	Emphasis on individual blame, thereby ignoring system influences.	Levels of analysis beyond the individual point to system explanations for rejection (Derksen and Gartell, 1993; Havens, 1975).
Temporal Dimensions	One-off retrospective studies fail to capture process, discontinuation and causality.	Field experiments to observe the effects of different 'treatments' (i.e. types of diffusion media) over time (Berelson and Freedman, 1964).
Causality	One-off retrospective studies fail to distinguish correlation from causality.	Causality observed through naturalistic experiments (Mohr, 1966; Rogers et al., 1999).
Consequences	Pro-innovation bias stresses adoption over impact; one-off studies privilege early impacts or come too late to be of use in minimizing negative impacts.	Research captures positive and negative consequences of diffusion or monitors impacts through time (Hightower, 1972; Sharp, 1952).
Technology	Failure to capture interdependencies among or clustering	Research to discern functional relationships among and degree of clustering

Clusters	of innovations.	of innovations (LaRose and Atkin, 1992; Silverman and Bailey, 1961).
Methods	Failure to integrate qualitative and quantitative methods.	Integration of survey methods with ethnographic analysis (Belasco, 1989).

Table 2. Methods Utilized to Address each Research Question

Research Question	**Methods**
Pros and Cons of the Technology	- Focus group discussions (pre).
Major Adoption Barriers	- Focus group discussions (pre & post). - Tracking survey.
Social and Farming System Niches	- Focus group discussions (pre & post). - Tracking survey. - Semi-structured interview. - Farm visits.
Farmer Innovations	- Focus group discussions (pre). - Semi-structured interviews. - Farm visits.
Social Networks	- Tracking survey. - Focus group discussions (post).
Livelihood Impacts	- Focus group discussions (pre & post). - Semi-structured interviews. - Tracking survey.
Agroecosystem Impacts	- Focus group discussions (pre & post). - Semi-structured interviews. - Tracking survey.

Table 3. Aspects of the Proposed Methodology as a Function of Past Critiques

Evaluation Criteria	**Positive Aspects of the Proposed Methodology**	**Limitations of the Proposed Methodology**
Characteristics of Adopter Categories	Integrates local perceptions of adopter characteristics with externally defined variables and quantitative assessments.	Snowball sampling biases adopters, losing perspective on how characteristics of adopters and non-adopters differ in the absence of a 'control.'
Attributes of the Innovation	Integrates attributes of local salience into survey and allows comparison of adoption patterns of several innovations at once.	Lacks systematic assessment of the role of '5 attributes' known to be common across innovations (Rogers, 2003).
Diffusion Networks	Identifies social characteristics of exchanges and tracks innovations through actual networks.	Less emphasis on the role of change agents, opinion leaders and broader social structure in diffusion.
Re-invention	Qualitative methods (focus groups, case studies) enable identification and description of farmer innovations.	Source and pro-innovation biases emphasize introduced and static over dynamic endogenous innovations.
Level of Analysis	Qualitative methods enable both individual and system influences to be identified.	Prioritizes perceptions of farmers over other actors in the system.
Temporal Dimensions	Tracking diffusion through 'levels' of spillover mimics temporal patterns and explicitly identifies reasons for discontinuation.	'Level of spillover' is an imperfect proxy for time; the opportunity to capture the influence of different actors and media as in naturalistic experiments is lost.
Causality	Integrates local and scientific interpretations of causality.	One-off studies deduce causality from expert opinion (farmers and researchers) rather than direct observation.
Consequences	Integrates methods (qualitative, quantitative); consequences (social, biophysical); and views (adopter, non-adopter, scientist).	One-off studies either privilege early consequences or results come too late to be of use in minimizing negative consequences.
Technology Clusters	Simultaneous tracking of innovations and farmer interpretations of findings.	Using 'levels of spillover' to track diffusion emphasizes discrete innovations or pre-defined clusters.

Methods	Integrates qualitative methods (for pattern recognition, interpretation) with quantitative methods.	Tracking adoption through ‘levels of spillover’ privileges adopters, although discontinuation is also identified.

Table 4. Adoption Barriers Identified through Focus Group Discussions

Technology	**Adoption Barriers Identified by Farmers**
Banana Germplasm	Low availability of planting material (suckers); susceptibility to drought.
Cabbage Germplasm	High cost of seed.
Organic nutrient resources	Limited knowledge on how to make compost; limited alternative uses of *Mucuna*; lack of compost materials; limited awareness.
Soil and Water Conservation	Presence of annual crops; labor requirements and old age; organic nutrient resource requirements; limited access to technical assistance.[a]
Tomato Germplasm	Labor requirements; input requirements; limited access to irrigation & quality land; dislike of industrial pesticides; limited access to technical assistance (for agronomic practices).

[a] Tables 5 and 6 illustrate how locally-identified variables, such as these identified for soil and water conservation technologies, are integrated into formal tracking surveys.

Table 5. Survey Instrument for Technology Tracking (Generic Entries)

Name of Adopter	Nature of Exchange (Free, Sold, Exch.)	Exchanged (Germplasm, Assistance, Working Knowledge)	**Age**	Gender	Spillover Level (L_0, L_1, L_2,…)	Relation[a] (N, Fr, R/E, R/N, Other)	Household Characteristics							Other Technologies Adopted
							House-hold Labor	Plots Land	Acres Land	Who Owns Land ?	# Cattle (I/N)[b]	# Small Ruminants	Off-farm Income	

[a] Bold font indicates farmer-identified variables.

[b] N = Neighbor, Fr = Friend, R/E = Relative (extended family), R/N = Relative (nuclear family), O = Other.

[c] I = Improved breeds, N = Non-improved or indigenous cattle.

Table 6. Supplementary Survey Instrument for Tracking Soil Conservation Technologies ('Ground-Truthed' with farmer and researcher variables)

Name of Adopter	Techno-logy Adopted[a] (GS, BT, FJ)	**Access to Technical Assistance on SWC Technols.** (High, Med, Low)	**Farm or Landscape Location of Structures**[b] (slope; HH or OF; IL or NIL)[c]	Farming System Characteristics				Impact (Positive, Negative, None)[d]				
				Soil Quality Prior to Conserving (Good, Medium, Poor)	**Access to Irrigation Water**	**Access to Organic Nutrient Resources** (High, Med, Low)	**Land Area under Perennial Crops**	**Soil Water Holding Capacity**	**Soil Fertility**	**Weeds**	**Crop Vigor**	**Income**

[a] GS = Grass strips/fodder contours; BE = Bench terrace; FJ = Fanya Juu.

[b] Bolded black font denotes variables identified by farmers, and bolded grey font those identified by researchers.

[c] HH = near household; OF = in outfields; IL = irrigated land; NIL = non-irrigated land.

[d] While not included here and saying little about social or environmental impacts, total length of conservation structures is also often used as an impact variable.

Table 7. Social Networks Characterizing Spontaneous Spread of Technologies

Relationship	**Banana** (% exchanges)	**Soil Fertility Management** (% exchanges)	**Soil and Water Conservation** (% exchanges)	**Tomato** (% exchanges)	**Ave.** (%)
Kin	**53**	**43**	**40**	**57**	**48**
- (Nuclear Family)	(26.5)	-	(25)	(14)	(22)
- (Extended Family)	(26.5)	-	(15)	(43)	(28)
Non-Kin	**47**	**57**	**60**	**43**	**52**
- (Friend)	(41)	(28.5)	(36.5)	(21.5)	(31.9)
- (Neighbour)	(6)	(28.5)	(24.5)	(21.5)	(20.1)
Male adopters (L1)	**98**	**86**	**82**	**100**	**95**
Female adopters (L1)	**2**	**14**	**18**	**0**	**5**

Table 8. Types of Exchanges for Different Technologies

Type of Exchange	**Banana** (% exchanges)	**Soil Fertility Management** (% exchanges)	**Soil and Water Conservation** (% exchanges)	**Tomato** (% exchanges)	**Ave.**
Free	88	67	75	57	71.8
Sold	12	0	0	43	13.8
Exchanged	0	33	25	0	14.5

Table 9. Agroecosystem Impacts Identified by Farmers

Type of Impact	**Banana**	**Soil and Water Conservation**	**Tomato**
Impact on other system components	Favorable effects on coffee and other crops when intercropped.	Positive effect on banana (from soil fertility and moisture effects) and livestock (fodder production).	Some farmers have begun fallowing hillside plots used for staple crops due to increased time allocated to cash crop cultivation in valley bottoms.
Input requirements	Increased demand on fertilizer at farm level given the high level of organic matter input during establishment.	No outside inputs identified.	More pesticide and inorganic fertilizer use given crop demands and extended periods of cultivation.
Land, labor and nutrient allocations	Recommended spacing takes up more land; greater labor investments during planting and mulching.	Substantial diversions of organic nutrients and labor from other farm activities during terrace establishment.	Substantial diversions of land, labor and nutrients from coffee and maize.
Pests and disease	None observed.	Reduction in maize stem borer.	Increase in pests and wilting disease due to decreased crop rotation and diversity.
Soil	Mulching has increased soil fertility and water holding capacity and reduced erosion.	Positive or negative impacts depending on levels of organic amendments.	Increased water holding capacity and fertility from manure usage.
Weeds	Sharp reductions due to mulching.	Increase in weeds near the Napier grass.	Increased along with soil fertility.

FIGURES

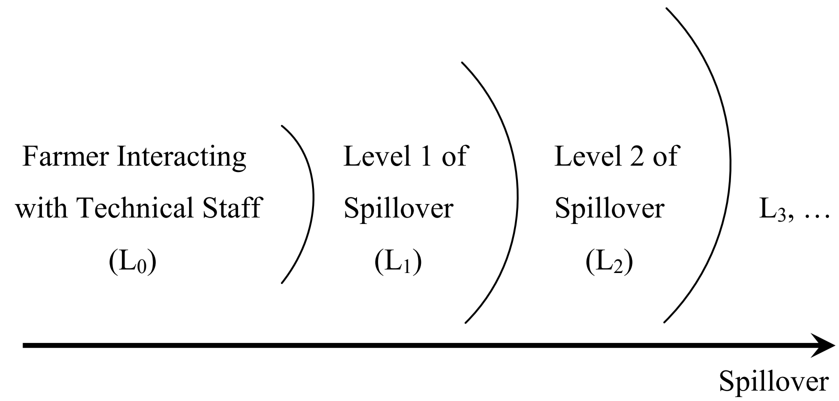

Figure 1. Levels of Technology "Spillover" Relative to Project Interventions

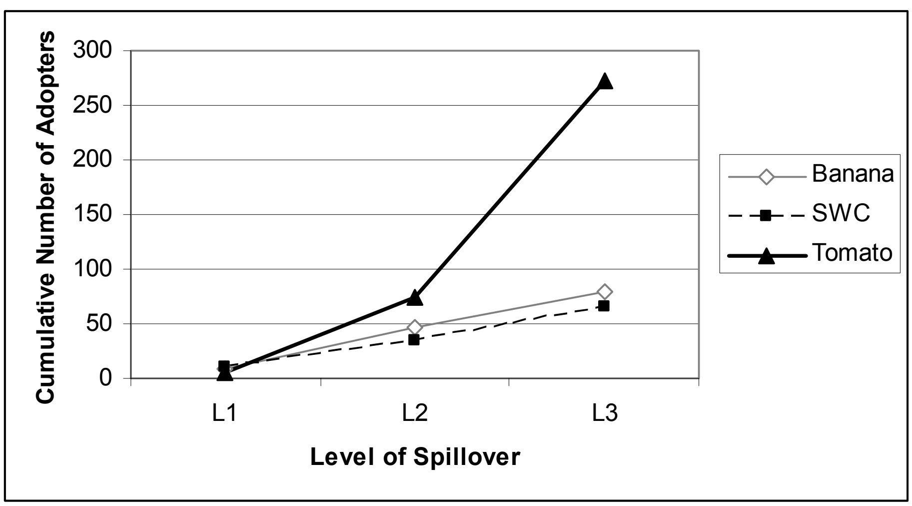

Figure 2. Relative Rates of Adoption of Introduced Technologies