Blending 'Hard' and 'Soft' Science: The 'Follow-the-Technology' Approach to Catalyzing and Evaluating Technology Change

Article *in* Conservation Ecology · January 2003

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Douthwaite, B., N. C. de Haan, V. Manyong, and D. Keatinge. 2001. Blending "hard" and "soft" science: the "follow-the-technology" approach to catalyzing and evaluating technology change. Conservation Ecology **5**(2): 13. [online] URL: http://www.consecol.org/vol5/iss2/art13/

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Synthesis, part of Special Feature on Integrated Natural Resource Management

Blending Hard and Soft Science: the Follow-the-Technology Approach to Catalyzing and Evaluating Technology Change

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ABSTRACT

The types of technology change catalyzed by research interventions in integrated natural resource management (INRM) are likely to require much more social negotiation and adaptation than are changes related to plant breeding, the dominant discipline within the system of the Consultative Group on International Agricultural Research (CGIAR). Conceptual models for developing and delivering high-yielding varieties have proven inadequate for delivering natural resource management (NRM) technologies that are adopted in farmers' fields. Successful INRM requires tools and approaches that can blend the technical with the social, so that people from different disciplines and social backgrounds can effectively work and communicate with each other. This paper develops the "follow-the-technology" (FTT) approach to catalyzing, managing, and evaluating rural technology change as a framework that both "hard" and "soft" scientists can work with. To deal with complexity, INRM needs ways of working that are adaptive and flexible. The FTT approach uses technology as the entry point into a complex situation to determine what is important. In this way, it narrows the research arena to achievable boundaries. The methodology can also be used to catalyze technology change, both within and outside agriculture. The FTT approach can make it possible to channel the innovative potential of local people that is necessary in INRM to "scale up" from the pilot site to the landscape. The FTT approach is built on an analogy between technology change and Darwinian evolution, specifically between "learning selection" and natural selection. In learning selection, stakeholders experiment with a new technology and carry out the evolutionary roles of novelty generation, selection, and promulgation. The motivation to participate is a "plausible promise" made by the R&D team to solve a real farming problem. Case studies are presented from a spectrum of technologies to show that repeated learning selection cycles can result in an improvement in the performance of the plausible promise through adaptation and a sense of ownership by the stakeholders.

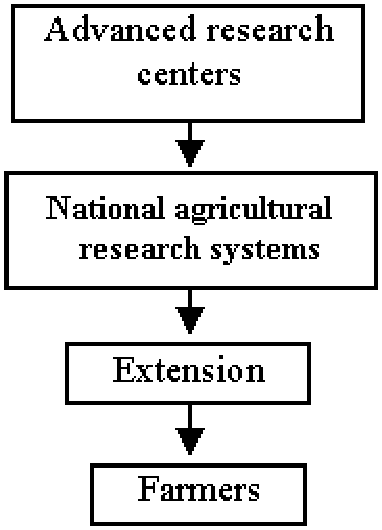
KEY WORDS: actor-oriented approach, follow-the-technology approach, integrated natural resource management, learning selection approach, participatory technology development, social construction of technology.

Published: December 20, 2001

INTRODUCTION

On its Web site (www.inrm.cgiar.org), the Consultative Group on International Agricultural Research (CGIAR) defines integrated natural resource management (INRM) as "the responsible and broad-based management of the land, water, forest, and biological resources base—including genes—needed to sustain agricultural productivity and avert degradation of potential productivity." A workshop held in August 2000 titled Integrated Natural Resource Management in the CGIAR concluded that implicit in this definition is a focus on human well-being and thus an emphasis on systems rather than commodities and on processes rather than technologies (International Center for Living Aquatic Resources Management 2000). As such, INRM is attempting to carry out types of research and intervene in ways that are very different to the yield improvement work that has been CGIAR's mainstay in the past. CGIAR centers have achieved most of their impact by delivering improved varieties to relatively simple environments. The new knowledge is embedded in the seed, which farmers already know how to plant and save; few or no new management skills or changes to routine are needed (Douthwaite et al. 2001). As a result, researchers have been able to assume a simple, rather linear view of the technology development and transfer process, which is described by Chambers and Jiggins (1986) as the transfer-of-technology (TOT) view presented in Fig. 1. The widespread success enjoyed by the TOT approach in starting the Green Revolution has helped to ingrain the approach to such an extent that it has been commonly applied to the development and transfer of types of technology other than improved germplasm (Kaimowitz et al. 1989).

Fig. 1. The transfer of technology (TOT) view of the way innovations originate and are passed down to farmers (adapted from Chambers and Jiggins 1986).



Since the publication of the landmark paper describing the "farmer-back-to-farmer" approach (Rhoades and Booth 1982), there has been a growing realization within the CGIAR system that the TOT approach is flawed. One indication of the problem is the failure of natural resource management research to achieve adoption rates similar to those of plant breeding. For example, in a recent comprehensive review of research on soil fertility in West Africa, Bationo et al. (1998:33) concluded that " ... over the past years a considerable amount of technologies to improve the productive capacity of African soils have been generated. These technologies have not been transferred or implemented by the intended beneficiaries." The unhappy situation is that in many parts of Africa farmers have little choice but to continue to degrade their soils and their environment. It is just this scenario that INRM was set up to address. But how will INRM achieve its goals in practice? What tools and methodologies are INRM practitioners going to use?

A CLASH OF TWO PARADIGMS

If everyone saw the world in the same way, then making INRM operational would simply be a matter of agreeing on a few tried and trusted methodologies with the stakeholders involved and then following the formula to implement them. However, life is not that simple. On the one hand, INRM practitioners are going to have to work with colleagues in the CGIAR system and in the national agricultural research systems (NARS) who feel that if they cannot come up with something better than what the farmers are already doing, then they should give up and go home. These colleagues generally find that they agree with the underlying principle of the TOT approach, i.e., that scientific knowledge is, or certainly should be, superior to farmers' knowledge, and so have a problem relating to participatory approaches that eulogize farmers' knowledge. On the other hand, INRM practitioners will have to work with farmers who may ignore realities that seem obvious to scientists. Hence, understanding that people see reality differently and the ability to negotiate shared realities are fundamental to successful INRM implementation. Constructivism is the epistemological basis of INRM that supports the idea of multiple realities. Understanding the difference between the constructivist paradigm and the positivist-realist paradigm, which underpins the "science-is-best" basis of the TOT approach, is important to comprehending the nature of the paradigm change necessary to make INRM operational within the CGIAR system and NARS.

Positivist-realism is associated with "hard" science, which sets up hypotheses and tests them with repeatable and quantifiable experiments. Practitioners of hard science (e.g., most natural scientists and some social scientists) are trained to believe that the world they experience has an independent reality that they are discovering in their experiments. The repeatability principle implies that knowledge gained in this way is independent of its context and separate from the individual. A corollary of this view is that, because scientific rules are universal, then people need to change, not technology. Furthermore, because scientific knowledge has passed the rigor of the scientific process, it is seen as superior to farmers' indigenous knowledge, which generally has not. Hence, the TOT approach, applied in its purest form, stipulates that the role of agricultural scientists is to use the scientific method to understand, structure, and model reality to develop technologies that benefit farmers. It is then the job of extension to "project" the scientists' knowledge onto the minds of farmers as accurately as possible, and the responsibility of the farmers to receive it. Farmers are supposed to be passive recipients in that they are not expected to adapt the message if it is based on "good" science and properly delivered. If farmers do not adopt it, it is their fault for being backward.

Constructivism is associated with "soft" science, which looks at social phenomena that cannot be reduced to their component parts or repeated outside of their complex settings. Case studies that paint a rich, thick picture of phenomena are a mainstay of the soft sciences. Constructivism provides the epistemological foundation for "participatory" approaches. Soft scientists contend that, contrary to the realist-positivist position:

- knowledge is not passively received and "mapped" onto a learner's brain but is actively "constructed" by the learner, who fits it into his or her existing mental maps or, less commonly, constructs a new model of reality and makes it part of his or her lifeworld. This construction process is social, because the mental maps may be culturally defined, and because part of the interpretation is undertaken by a group through negotiation; and

- people's ability to learn and understand is adaptive in the evolutionary sense, in that cognition serves a person's need to process information to conceptually organize and understand the world he or she experiences as a means of survival. In the words of Maturana and Varela (1987), " ... knowledge is effective action in the domain of existence," and there is nothing absolute or external about it.

In practice, few, if any, scientists in the CGIAR system today would ever see farmers as completely passive adopters of a message. Nevertheless, most people would agree that positivist-realism, rather than constructivisim, is still the dominant paradigm in many CGIAR centers and in most national research systems. Therefore, it will require a paradigm shift for INRM to become a mainstream activity. Paradigm changes are not easy, as Thomas Kuhn (1970) points out; he notes that scientists will go to great lengths to defend their belief structures, to the extent that research is not about discovering the unknown, but rather " ... a strenuous and devoted attempt to force nature into the conceptual boxes supplied by professional education." To this end, a research community will often suppress novelties that undermine its foundations. Like the research into farming systems that was carried out in the 1980s, INRM runs the risk of being dismissed on the grounds that it is too woolly and has little quantifiable impact. The Bilderberg Consensus, which helped establish INRM within the CGIAR system, identified improved adaptive management as the key to achieving relevance and impact in INRM, and hence avoiding the fate of farming systems research. Adaptive management is essential because, as Campbell et al. (2001) point out, there is an inverse relationship between the complexity of systems (INRM systems are complex) and our ability to make precise and yet significant statements about their behavior.

The successful introduction of INRM technology can have unexpected and even negative consequences, as one of the present authors learned first-hand in Tanzania (N. C. de Haan and E. Musuyaka, *unpublished manuscript*). In the early 1990s, an NGO in Tanzania ran a project to improve child nutrition. It introduced an agro-ecologically well-adapted bean variety that was more nutritious than local varieties. The NGO targeted its technology at women, who are traditionally in charge of feeding the family. The new variety of bean proved very popular, and its adoption rate soared. Despite this, after the first few years, the nutritional benefits for local children had evaporated. It eventually emerged that the bean had also proved popular among men, who started to cultivate it for the market on land that had previously been women's property for growing food for home consumption. So, instead of the technology helping the targeted group, it in fact benefited another group to the detriment of the first.

INRM activities need management strategies that adapt as they go along to ensure that the project has impacts that are, on balance, positive. Successful management strategies in INRM therefore need to be based on effective monitoring and evaluation systems to guide learning. Given that change is expected during the course of a project, the monitoring and evaluation system itself must also be adaptive and flexible.

In this paper we develop the "follow-the-technology" (FTT) approach to guide the fostering and evaluation of technology change in the context of INRM. The approach needs to be:

- comprehensive and adaptive enough to deal with the complexity of INRM systems and
- constructed from language and concepts that both hard and soft scientists can understand and relate to.

The second requirement may be rather hard to achieve. The present authors come from both hard and soft science backgrounds and, while we were writing this paper, we had to negotiate a shared understanding between ourselves and our two guiding paradigms. We hope this is reflected in the paper and is useful for others.

DEVELOPING THE FOLLOW-THE-TECHNOLOGY APPROACH

Learning selection: the core model

The model at the core of the follow-the-technology (FTT) approach is the learning selection (LS) model (Douthwaite 2001, Douthwaite et al. 2002) that describes the "social construction" and adoption of new technologies, including machines, seeds, computer software, and financial systems. The LS model is based on an analogy between technology change and Darwinian evolution that is recommended as being useful in understanding innovation processes (Nelson 1987, Mokyr 1990). This evolutionary analogy suggests that technology change is driven by a process analogous to natural selection. We call this analogy "learning selection," but it is not a perfect analogy. Rather, it is an "analogy as a heuristic," or an analogy that suggests useful ways of thinking about innovation processes from the point of view of the much better understood evolutionary process (Ruse 1986).

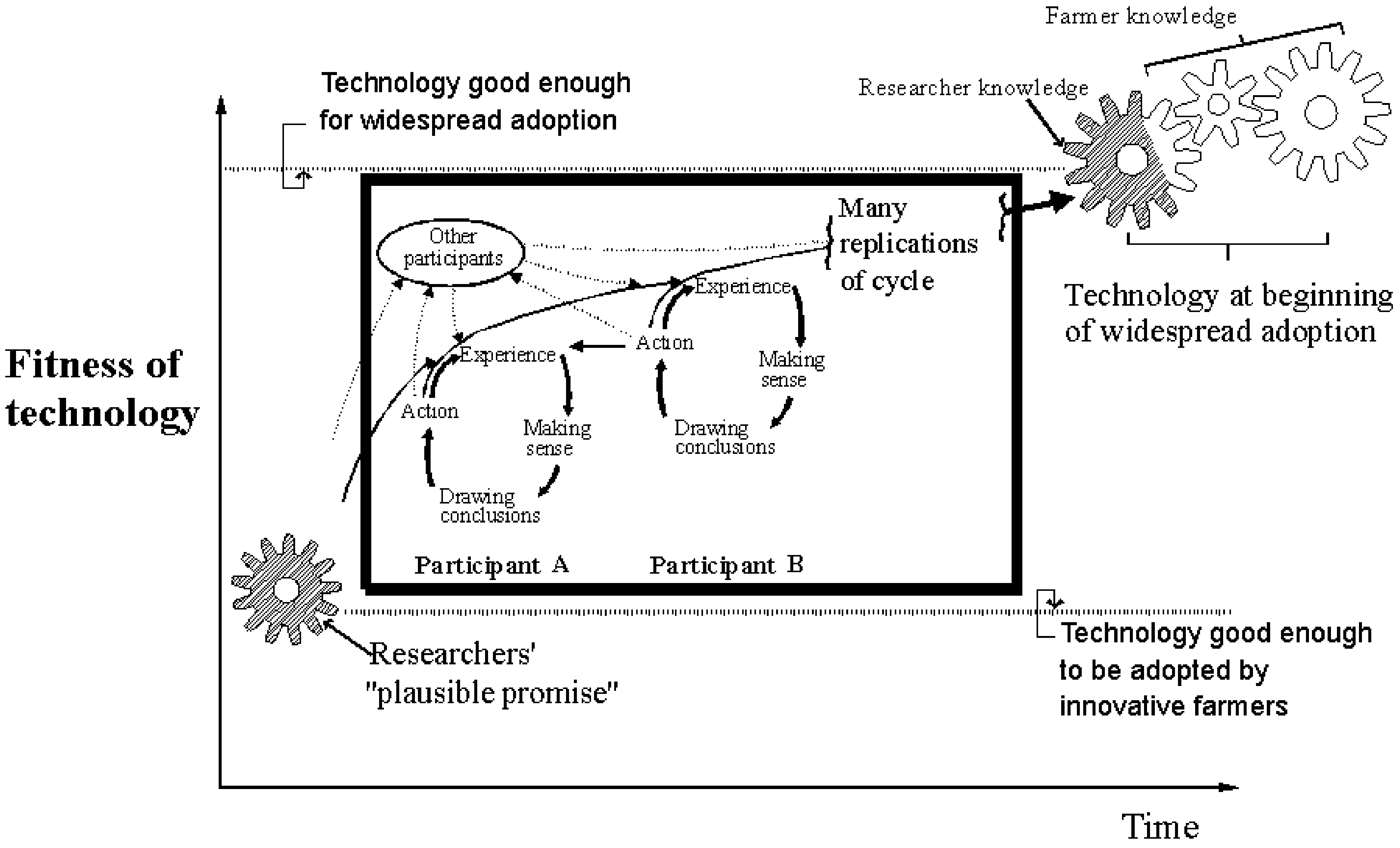
The Bilderberg Consensus has already identified evolutionary approaches as areas of potential breakthrough for INRM. We believe that one reason why this prediction may become reality is because both positivists and constructivists understand and accept Darwin's theory of natural selection and will be comfortable thinking about technology and system change in evolutionary terms. For this reason, the analogy is a good basis for negotiating a shared understanding. Moreover, as Dawkins (1995:*xi*) wrote, "Never were so many facts explained by so few assumptions ... the Darwinian theory command(s) superabundant power to explain." Finally, the specific analogy we are suggesting, between natural selection and learning selection, highlights the learning processes of the actors involved in INRM, something that Campbell et al. (2001) identify as key to the effective management of complex systems.

Natural selection consists of three mechanisms:

- *Novelty generation.* As a result of random genetic mutations and sexual recombination of differing genetic material, differences between individual members of a species crop up from time to time.
- *Selection.* This is the mechanism that retains random changes that turn out to be beneficial to the species because they enable those possessing the trait to achieve better survival and breeding rates. It also rejects harmful changes.
- *Promulgation and diffusion.* These are the mechanisms by which the beneficial differences are spread to other areas.

To understand how learning selection is analogous to natural selection, let us take the example of one of the stages in the early adoption of *Mucuna pruriens* in Benin (Fig. 2). *M. pruriens* is a herbaceous legume that forms the basis of an NRM cover crop and green manure technology. Participant A is a female farmer who decides to plant an *M. pruriens* cover crop in her field after seeing a demonstration in her village by researchers that shows the legume's ability to improve soil fertility. As a result of growing *M. pruriens,* the farmer has an experience of the crop that she tries to interpret on the basis of the information in her existing mental models of reality. Her observations and understanding lead her to the conclusion that *M. pruriens* is more immediately useful as a way of suppressing *Imperata cylindrica,* a grass weed that caused her to abandon some of her land. The following year, she uses *M. pruriens* to try to reclaim this land by cutting the *I. cylindrica* at the beginning of the rainy season and broadcasting *M. pruriens* seed in the hope that it will outgrow and smother the *I. cylindrica.* By carrying out this experiment, she is generating a novelty as well as beginning another learning cycle, the result of which will be a selection decision on her part as to whether to continue to plant *M. pruriens* in this way.

Fig. 2. The learning selection model, which shows how the fitness of a technology changes during the early adoption phase.



Other people, including farmers, researchers, and laborers, might also observe Participant A's experiment and, as a result, experience their own learning cycles, resulting in their own changed perceptions and actions (Fig. 2). For example, participant B might be a researcher who learns that the ability of *M. pruriens* to suppress *I. cylindrica* is more important to farmers than its ability to improve soil fertility. Learning this would then influence further researcher novelty generation and selection decisions, as well as efforts to promulgate and diffuse the technology. The net effect of all these learning selection cycles is to improve the fitness of the technology, i.e., its suitability for the environment in which it is used, and hence its market appeal and adoption rate. This is analogous to the fitness increases that occur in the living world as a result of natural selection. The concept of fitness or adoptability in the sphere of human activity is also similar to Lyotard's (1984) concept of performativity, which he defines as the best possible input:output ratio. Lyotard argues that performativity itself is the main way to legitimize knowledge.

Learning selection, however, does not just happen. It comes about only if the key stakeholders, i.e., the people directly involved in using and replicating the technology, are sufficiently motivated to modify it; they must also have sufficient knowledge to generate and select beneficial changes. Experience shows that, for all but the simplest technologies, there is a need for at least one stakeholder who understands the technology to champion it and fill knowledge gaps until the key stakeholders have learned enough to take over (Douthwaite 1999). This takeover marks the end of the early adoption process and is the point at which market selection, as opposed to learning selection, begins to work. As this happens, the people adopting the technology change from Rogers' (1995) "innovators" to people who want the technology to work reliably and profitably.

According to Merriam-Webster (2001), technology can be defined as " ... the practical application of knowledge ... " (by people). If all technology can be thought of in terms of knowledge, this definition implies that there is no inherent difference between agricultural and other types of technology. Hence, agriculture and INRM can potentially learn much about technology change from other fields. To determine whether or not it was possible to generalize the LS approach, Douthwaite (2001) tested it by looking at the extent to which it fit outside agriculture, and explored ways in which the model could be strengthened by experience and literature from other fields. He found that, not only is the LS model much more widely applicable, but the democratic user-led type of innovation it describes is able to harness the innovative potential of the people who are directly affected by the technology. Douthwaite shows how a grassroots development process in Denmark was able to produce a wind turbine industry with a 55% share of a world market worth U.S.$1 billion per year, surpassing even the United States, which spent more than $300 million funding a top-down development program led by the National Aeronautics and Space Administration (NASA). The origins of the Danish industry were a few agricultural machinery manufacturers and ideologically motivated hobbyists who began building and tinkering with wind turbines (generating novelty). There were many early teething problems but the owners organized themselves into a group who lobbied successfully for design improvements (selection), working closely with manufacturers to solve problems. The owners group developed a cooperative ownership model and pressured politicians to support the sale of their electricity to the national grid at a fair price (promulgation and diffusion). In contrast, NASA led a hard science development approach that implicitly assumed that scientists could develop the perfect wind turbine with little input from owners and users. NASA's approach failed.

Another example of the power that a grassroots innovation model can harness is the development of the computer operating system Linux, which is a " ... a world-class operating system ..." that has coalesced " ... as if by magic out of part-time hacking by several thousand developers all over the planet connected only by the tenuous strands of the Internet ... " (Raymond 1997). Linux started life when a Finnish computer science student, Linus Torvalds, wrote a Unix-like operating system that he could run on his PC; he had grown tired of having to queue for hours to gain access to Unix on the university mainframe. When he finally got the core of his operating system working, he posted it on the Internet so that others could try it out. Best of all, he gave out the source code so that other people could understand the program and modify it if they wanted to. Just like the first Danish wind turbines, early versions of Linux were not technically sophisticated or elegant, but they were simple and understandable, and they touched a chord with hackers and people like Torvalds himself who get a kick out of generating novelty for the sake of being creative, not for money.

After the first release, Torvalds' main role in the development of Linux was not to write code for features people wanted, but to select and propagate improvements to the system from the ideas that streamed in. Ten people downloaded version 0.02, and five of them sent him bug fixes, code improvements, and new features. Torvalds added the best of these to the existing program along with others he had written himself and released the composite as version 0.12. The rate of learning selection accelerated as the number of Linux users increased, and, to cope with the volume of hacks (novelties) coming in, Torvalds began relying on a type of peer review. Rather than evaluate every modification himself, he based his decisions on the recommendations of friends he trusted and on whether people were already using the patch (modification) successfully. He, in fact, played a similar role to that of the editor of an academic journal who makes sure that submitted articles are reviewed but retains final control over what is published and what is not. This approach allowed Torvalds to keep the program on track as it grew from 10,000 lines of code to 1.5×10^6, all written by volunteers.

Such has been the success of Linux that Microsoft, which until recently was the richest company in the world based on market capitalization, is privately worried. Vinod Valloppillil, a Microsoft engineer, analyzed the open-source software movement in a confidential memorandum that was leaked and posted on the World Wide Web. Valloppillil (1998) wrote, "Linux could win ... The ability of the open source software process to collect and harness the collective IQ of thousands of individuals across the Internet is simply amazing." Microsoft jealously guards its own source code to make sure it remains closed, and users cannot modify it. Although Linux is not yet seriously threatening Microsoft's 90% domination of the PC market, by the end of 1998 Linux was installed on 17% of the servers that run computer networks, including the Internet, which was a 7% increase from the previous year. Windows NT, the market leader, remained fairly static at 38% (Shankland 2000).

The fact that a grassroots community development model can lever more creative talent than one of the richest companies in the world has, we feel, an exciting resonance for INRM. To succeed in complex environments, INRM interventions must be able to foster and motivate the innovative potential of local people, or else scaling up from pilot site to landscape will not occur. Douthwaite (2001) has developed a practical guide on how to launch and manage a learning selection innovation process by starting with a plausible promise and then building a development community of motivated users. The guide, which is presented in Appendix 1, is intended for R&D managers working in the public or private sector.

The analogy between natural selection and learning selection is not perfect. One important difference is that natural selection is blind, whereas learning selection is not: genetic mutations occur at random, but technology and system change can be directed, e.g., by product champions. The "thinking" nature of learning selection implies that, to understand the processes involved, we have to go beyond simply identifying novelties generated or selection decisions made and delve into the reasons why people behave the way they do. Consequently, a cornerstone of the LS approach is the seemingly obvious relationship articulated by Lewin (1951), who maintains that people's behavior (*B*) is a function of the interaction of the person (*P*) with his or her environment (*E*), or $B = f(P,E)$. This is the theoretical justification for the fourth and fifth steps in the guide (Appendix 1) to managing a learning selection approach that involves working with motivated people and choosing pilot sites where there is a real need. MacKeracher (1994) explains the Lewin model in this way. Behavior can include any outcome of the learning process, including adoption, modification, selection, a change in attitude, and communication to others. *P* stands for the person (the learner) and can include any characteristic that affects learning, such as existing models of reality. *E* stands for the environment and can include any factor within the context that might affect learning, including the number and quality of interactions with other people, the nature of the technology being tested, and the physical, cultural, and socioeconomic settings.

Whereas the learning selection model has been developed and verified on several types of technology, including seed-based technology (Douthwaite 2001), it has not been used in an INRM context to initiate or manage innovation. As we've already acknowledged, INRM needs to operate in complex settings. These settings are likely to involve more complex social interactions than the learning selection model has so far dealt with, and therefore it needs to be adapted and expanded to take this into account. In particular, a rather more robust framework is needed than that provided by Lewin's model, which does not take into account the groups, social learning, or social organizations surrounding technologies.

Understanding people's actions: the actor-oriented approach

This is where the actor-oriented (AO) approach, developed by Norman Long (1997) at the Wageningen Agricultural University, can help, because it seeks to understand how different stakeholders react to technical and social change by concentrating on three interlocking analytical concepts: intervention, interface, and lifeworlds.

Intervention

Long (1989) describes intervention as an attempt from outside a system " ... to organize and control production ... " within it. The introduction of a new agricultural technology is therefore an intervention into an already existing situation. The focal point of interest in the actor-oriented approach is how people negotiate and transform this technology (used here in the broadest sense of the word). The intervention results in actual changes to the status quo and the expectation of further changes. These changes are what Long (1992) calls "structural discontinuities," and they are what people react to when they decide how they are going to adapt and transform the technology and their social networks to fit into their own mental maps of reality or lifeworlds. One possible reaction is, of course, to ignore the technology and to try to maintain one's lifeworld unchanged. It is exactly these reactions, or lack of them, that the AO approach seeks to identify and study.

Lifeworlds

Lifeworlds are the realities that people adaptively construct for themselves. They are the sum total of the mental maps and models that people have built to allow them to cope in their environments and, as such, are made up of past experience and personal and shared understanding. Lifeworlds are what lead people to react in the ways that they do when they confront an intervention (a new technology). Thus, the lifeworld concept encompasses both the people and part of the environment construct in Lewin's (1951) model. Schütz and Luckmann (1974) describe a lifeworld as a " ... lived-in and largely taken-for-granted world." This taken-for-granted nature of lifeworlds makes them difficult to study, because people often do not understand the concept or realize the limits of their own lifeworlds unless they are challenged (Long 1992). The methodological importance of the lifeworld concept is that it explicitly acknowledges that people have different realities and makes understanding these realities a primary research activity. This is very different from more traditional approaches that put a premium on the scientist's understanding of problems and solutions.

Interface

The interface concept is closely linked to that of intervention. Social interface is defined by Long (1989) as " ...

the critical points of intersection or linkages between different social systems or levels of social order, where structural discontinuities based upon differences of normative values and social interest are likely to be found." In other words, interfaces are the areas in which different social groups experience mutual friction and, if the introduction of a new technology is going to cause problems or create opportunities (i.e., structural discontinuities), the interface is where they will be found. Long goes on to say that " ... the concept implies face-to-face encounters between individuals or social units representing different interests and backed by different resources." It is by identifying these interfaces and then studying the perturbations that occur as a result of the intervention that we can understand how interventions are modified by everyday life, and vice versa (Arce and Long 1992). The interface concept is thus contained within Lewin's concept of environment in his model.

Methodologically identifying interfaces is important, because they allow us to identify all the groups that are involved in and influenced by a technology without overlooking something important, as happened in the Tanzanian bean example.

The concepts and value of intervention, lifeworlds, and interface can be illustrated with an example from the Philippines (Douthwaite et al. 2002). A mechanical rice harvester was introduced into the Philippines in 1983 by both the public and private sectors. This was the intervention. Initially, the machine was purchased by hundreds of farmers (one social group) who wanted to reduce wage payments to manual harvesting teams (another social group). The traditional arrangements surrounding the hiring of harvest labor teams by farmers was the interface, and the structural discontinuity was the farmers' decision to depart from these arrangements and use the machine instead. The harvest laborers found themselves out of work and started sabotaging the reapers by hiding iron rods in the rice crop that broke the reaper cutter bar. The harvest laborers also started to refuse to harvest fallen crop manually or to harvest in muddy fields where the reaper could not work. Finally, they boycotted other farm operations, such as transplanting and weeding on the adopting farmers' fields, resulting in a structural discontinuity at another interface. Some reaper owners abandoned their machines, and the adoption rate fell sharply.

The structural discontinuities led to negotiations between the two groups that resulted in an institutional innovation (an emergent structure) that has allowed both groups to incorporate the reaper into their lifeworlds. The manual harvest teams started to hire the reapers from the owners, because they found that the machines allowed them to harvest more crop and increase their net income. As a result, they were able to share in the benefits of the technology, and their attitude toward it changed.

THE FOLLOW-THE-TECHNOLOGY APPROACH IN PRACTICE

As we've seen from the bean and reaper examples, we need a methodological approach to INRM that is adaptive and flexible enough to be able to respond in a timely way to unexpected events and unintended consequences. The problem with "cookbook" approaches to monitoring and evaluation is that they all come with fixed preconceptions, embodied in the indicators chosen, of what is going to be important. The methodological importance of the follow-the-technology (FTT) approach is that it does not try to predict the future in this way. Rather, it does what the name suggests and follows the technology, using this intervention as the entry point into a complex situation, and then allowing what is discovered to determine what is important. In this way, it narrows the research arena to fit within achievable boundaries. In practice, we should attempt to follow the progress of the technology from first adoption by identifying and asking the classic journalistic questions (What? Why? Who? When? Where? How?) about the:

- novelties generated,
- selection decisions made, and
- promulgation mechanisms used.

Furthermore, we should be looking for these effects in areas of interface while seeking to understand people's realities and how they affect the answers.

The FTT approach as a monitoring and management tool

Researchers in Nigeria (G. Tarawali, B. Douthwaite, N. C. de Haan, and S. A. Tarawali, *unpublished manuscript*) have demonstrated the relevance of the FTT approach to INRM. This approach is currently being applied to the monitoring, evaluation, and ex ante impact assessment of the following project.

In the late 1990s, scientists from the International Institute of Tropical Agriculture (IITA) in Ibadan, the International Livestock Research Institute (ILRI) in Nairobi, Kenya; the International Centre for Research in the Semi-Arid Tropics (ICRISAT) in Hyderabad, India; the International Fertilizer Development Center (IFDC) in Muscle Shoals, Alabama, USA; and the University of Durham in Durham, UK, developed "best-bet" options or technology packages that sought to integrate the most appropriate solutions that each institute had to offer. The pilot site chosen was Bichi in the northern Guinea savanna in northern Nigeria, and the best bet was considered to be an improved version of an intercropping technique already used by local farmers, in which they alternated rows of sorghum with rows of cowpeas. In the best-bet version, two rows of ICRISAT's best sorghum variety were intercropped between four rows of IITA's and ILRI's best dual-purpose cowpeas, and planting densities were much closer than those traditionally used. The normal practice of local farmers is to plant early-maturing cowpeas at the start of the rains in alternate sorghum rows and later-maturing cowpeas for fodder in the remaining rows when the rains become more regular (Mortimore et al. 1997). The expectation in the design of the best-bet package was that farmers would be able to harvest two crops of the improved early-maturing cowpea.

Eleven farmers began a trial of a version of the best bet with fertilizer and pesticide (BB+) and one without these inputs (BB). Their agreement to try out the best-bet package represented the intervention in terms of the FTT approach.

After the first season, farmers and researchers had been through several interactive learning selection cycles (see Fig. 2) in which they had generated novelties and made selection decisions. Only one farmer had attempted to double-crop his improved cowpea. Rains at the time the first crop was harvested meant the other farmers decided not to cut down their cowpea plants for fodder, because they would not be able to dry them. Instead, they chose to continue harvesting the few late pods. However, the one farmer who did generate the novelty (a novelty to the community) of double-cropping had good results, and his learning experience influenced others to try double-cropping the following year. Researchers played an important role in promulgating the double-cropping innovation. The other mutual learning experience was that the BB (without inputs) treatment did not perform adequately. Farmers were insistent that, because the BB experimental plots occupied a large percentage of their farms, they were going to add fertilizer and pesticides. The experiment was changed as a result.

We are currently using the FTT approach to analyze the interface between the researchers and the farmers to determine the extent to which farmers adopted the best-bet technology because it seemed to make a plausible promise of benefitting them, or whether they had other reasons. We are also following the technology out into farmers' fields to see exactly how much of the technology they have adopted. We are using a geopositioning system to map the corners of fields where some level of adoption has taken place and then entering these data, as well as photographs and word descriptions, into a geographical information system. This database will help us identify any novelties that farmers may be generating, the selection decisions they are making, and the degree to which the technology is diffusing. We will then use a variety of survey and focus group tools to attempt to understand farmers' motivations for their actions. The concept of interaction indicates that we should look at how their membership in different groups affects farmers' participation, motivations, and behavior, whereas the concept of lifeworlds will lead us to explore how people's past experiences and current cultural practices affect the integration of technology into their systems (learning selection).

THE FTT APPROACH TO CATALYZING, MANAGING, AND MONITORING RURAL TECHNOLOGY CHANGE

The FTT approach can be used to catalyze rural technology change by following specific steps (Appendix 1), together with the monitoring and evaluation approach described above. In summary, the first step in the FTT approach takes place when researchers develop a solution to a real problem facing local farmers that at least some of the more innovative ones are willing to accept as feasible (the plausible promise). This plausible promise is the catalyst around which the product champion seeks to build and nurture a co-development team of researchers and key participants, i.e., those who have the most to gain and lose from the innovation. As such, the plausible promise is critical to project success. Whether or not a research intervention represents a plausible promise is determined by the adopters, not the researchers.

The monitoring and evaluation of the process that unfolds focus on identifying the novelties generated, selection decisions and mechanisms, and promulgation mechanisms. The actor-oriented analytical structure helps explain actions and outcomes through the concepts of the interface and lifeworlds, which may not be logical from a scientific perspective. These concepts can also help explain people's motivations, which drive adoption processes. For example, they can help the project champion understand the extent to which farmers are collaborating because they believe in the plausible promise, or whether they are adopting the technology because of other incentives, e.g., access to subsidized inputs or jobs for their relatives. It also forces the monitoring and evaluation team to look at all the actors involved in the process and not only those targeted by the research team that developed the best bet.

The FTT approach to monitoring and evaluation can also be used to follow and understand any technology change process, not just one that started with a plausible promise based on research. It can also be used to analyze the history of an innovation to understand existing adoption patterns. Such understanding is clearly important to managing ongoing INRM interventions and planning future ones.

CONCLUSIONS

Successful INRM requires people from different disciplinary and social backgrounds to work together. Epistemological differences between the hard and soft sciences may be one constraint to effective collaboration.

The follow-the-technology (FTT) approach to catalyzing, managing, monitoring, and understanding rural technology change was developed in this paper to provide a framework that both realist-positivists and constructivists can work with. The core model is based on an analogy between technology change and Darwinian evolution, which is much better understood. One strength of this analogy is that it can provide a basis for both hard and soft scientists to negotiate a common understanding and language, because normally both camps accept Darwin's theory.

Successful INRM also requires management and monitoring and evaluation systems to be adaptive and flexible, because the operational contexts will be complex and unpredictable. Rather than trying to measure and monitor everything that might be important during an INRM project, the FTT approach does what the name suggests and follows the effects of the project interventions. The focus of the monitoring and evaluation effort is then determined based on these findings, rather than on preconceived ideas of what is going to be important, who is going to be affected, and what criteria to measure. In this way, we expect that project managers will receive more relevant feedback faster and be able to make the changes necessary to promote beneficial impacts and avoid negative ones.

The FTT approach can also be used to catalyze technology change. We gave the example of Linus Torvalds, the developer of Linux, who was able to use a very similar approach to leverage more creative talent than Microsoft, one of the richest companies in the world. We believe that the FTT approach makes the plausible promise of being able to catalyze the innovative potential of the technology users, which is necessary to scale up the technology from the pilot site to the landscape.

RESPONSES TO THIS ARTICLE

Responses to this article are invited. If accepted for publication, your response will be hyperlinked to the article. To submit a comment, follow this link. To read comments already accepted, follow this link.

Acknowledgments:

The authors would like to thank the two anonymous reviewers for comments and suggestions that helped to make this a better paper. We would also like to thank Jeff Sayer and Bruce Campbell for their support and work, which helped to make this paper possible.

APPENDIX 1

The learning selection approach to co-developing innovations with users (after Douthwaite 2001).

1. **Start with a plausible promise.**
   The first step to take when attempting to induce change through learning selection is to produce a

"plausible promise," or something that convinces potential stakeholders that the new technology can evolve into a tool or process that they really want. Experience shows that it is difficult to enlist co-developers if the whole project is abstract. Mokyr (1990: 9) believes that the process of inventing plausible promises is by its nature something that " ... occurs at the level of the individual." He says that creating a plausible promise is " ... an attack by an individual on a constraint that everyone else has taken for granted." It is not something that lends itself to a broad consensus approach. Therefore, creating a plausible promise is often about doing excellent, groundbreaking science that produces something that at least a few innovators in the target group might find useful.

The plausible promise does not need to be refined or polished; it can be imperfect and incomplete. In fact, the less final it is, the more scope there is for the stakeholders to innovate and thus gain ownership of the technology. The more problems there are, then the greater the chances that the key stakeholders will give up in frustration. A delicate balance must be maintained.

2. **Find a product champion.**
   The next step is to identify the innovation or product champion. He or she needs to be highly motivated and have the knowledge and resources to solve problems. Someone from the R&D team is likely to be suitable, because he or she will probably have both the necessary technical knowledge and the motivation; it always helps if the product champion already has a stake in the technology. He or she must also have good people and communication skills because, to build a development community, it will be necessary to attract people, interest them in what is going on, and keep them happy working for the common cause. The product champion's personality is therefore crucial.

3. **Keep it simple.**
   Don't attempt to dazzle people with the cleverness and ingenuity of the prototype's design. A plausible promise should be simple, flexible enough to allow for revision, and robust enough to work well even when not perfect. The critical comments of your colleagues don't matter. Your potential co-developers' needs and knowledge levels do. For example, if you are designing a combine harvester and you know the manufacturers and farmers you'll be working with are familiar with a certain type of thresher, then use that in your design, even if it is technically not the most elegant solution. As John Gall (http://www.quoteland.com/qldb/author/59) said, "A complex system that works is invariably found to have evolved from a simple system that worked."

4. **Work with innovative and motivated partners.**
   Allow the participants in your learning selection process to select themselves based on the amount of resources they are prepared to commit. Advertise or write about your plausible promise in the media, do field demonstrations, or post on the Internet and wait for people to contact you. Don't give inquirers anything with a resale value for free. For example, if your prototype has an engine, then charge the market value for it. Otherwise, people may be motivated to adopt it to get something for nothing. In addition, people generally value something more highly if they have paid for it, and they will be more committed to sorting out the problems that emerge.

   On the other hand, you must make it clear to the first adopters that they are adopting an imperfect product and that they are working with you as co-developers. You need to reassure them that you will be contributing your own resources to the project and will not abandon them with a lemon. You should be prepared to offset some, but not all, of the risk they are taking in working with you. Getting the balance right is very important here, too.

5. **Work in a pilot site or sites where the need for the innovation is great.**
   Your co-developers will be influenced by their environment. Their motivation levels will be sustained for a longer period if they live or operate in an environment where your innovation promises to provide great

benefits. In addition, they are more likely to receive encouraging feedback from members of their own communities.

6. **Set up open and unbiased selection mechanisms.**
   a) *The product champion/selector.*
   As soon as you have the key stakeholders working with you and generating novelties, you need ways of selecting and promulgating beneficial changes. Initially, the product champion usually plays this role. An effective selector must be able and prepared to recognize good design ideas from others. This means that, when this person is also the inventor, he or she must be suitably receptive and thus able to accept that others might have better ideas.

   Very few people are capable of effectively championing their products and selecting novelties at the same time. This is because, to be good at the former, it is necessary to believe deeply in the product's benefits and be able to defend it against criticism. An effective selector, on the other hand, must keep an open mind and be able to work with others to question fundamental design decisions.

   If a product champion defends the technology too strongly or shows bias, then "forking" occurs, and the disaffected person or group branches off to do what he or they felt prevented from doing by the selector. It is good to have people test alternative design paths, but, if it is done in frustration or spite, then cliques form, making any comparison and subsequent selection between rival branches difficult. Creative talent is split, and energies can be dissipated in turf wars.

   b) *Alternative selection mechanisms.*
   Even if the product champion can be open-minded and unbiased, he or she may have problems convincing others. One option is to set up a review mechanism that is well respected by the key stakeholder community. There are a number of ways of doing this. Three that work are review by an independent organization, peer review, and the provision of enough information to potential adaptors that they can make informed selection decisions themselves.

7. **Don't release the innovation too widely too soon.**
   For the innovation to evolve satisfactorily, the changes the stakeholders make to it need to be beneficial, and, because those generating the novelties will have gaps in their knowledge, product champions should restrict the number of co-developers so that they can work with them more effectively. When people show enthusiasm for a prototype, it is very tempting to release it as widely as possible, but this should be resisted. The technology will always be less perfect than the inventor initially thinks.

   However promising the technology might appear to be, there are many things that can and will go wrong. First adopters need to be aware of this and have ready access to the product champion. Otherwise, their enthusiasm will quickly turn to frustration, and the product champion will end up defending the technology against criticisms when the problems appear. Once the product champion becomes defensive, he or she will be far less useful at solving problems.

8. **Don't patent anything unless it is to prevent someone else from privatizing the technology.**
   In learning selection, people cooperate with each other because they believe that all will gain if they do. The process is, therefore, seriously damaged if one person or group tries to gain intellectual property rights over what is emerging. First, the community spirit is damaged. Second, patents are monopolies that immediately reduce the novelty generation rate and thus slow down future development and the flow of ideas.

9. **Realize that culture makes a difference.**
   The Tanzania bean example given in the text shows just how much difference local culture can make. The negative impact of women being dispossessed from their land would not have happened in a culture that

gives women stronger rights to property. Culture can also influence the degree to which knowledge is guarded within a particular group, or spread around. Learning selection is going to be greatly impeded in cultures where new knowledge is carefully guarded, either by keeping it secret or taking out and enforcing intellectual property rights.

10. **Know when to let go.** Product champions need to become personally involved and emotionally attached to their projects to do their jobs properly. However, this makes it easy for them to go on flogging dead horses long after it has become clear to everyone else that the technology is not going to succeed. Equally, project champions can continue trying to nurture their babies long after they have grown up and market selection has begun. It is, therefore, a good idea to put a time limit on the product champion's activities.

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