29 Towards a New Approach for Understanding Interactions of Technology with Environment and Society in Small-scale Rice Farming

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Introduction

Modern agricultural technologies have been adopted in many Asian rice farming systems, particularly in areas with good agroecological conditions. But in other rice-growing areas, the adoption of modern technologies has been very slow (Binswanger and Pingali, 1989; Waddington *et al*., 2010). In West Africa, this has been particularly the case in upland rice cultivation (Richards, 1986; Dalton, 2004; Okry *et al*., 2011), but also in mangrove-swamp farming systems (Temudo, 2011). Modern technologies are often not adapted to local conditions. Since the 1980s, it has been recognized that farmers need to be more involved in variety development through participatory varietal selection (PVS) and decentralized breeding (Maurya *et al*., 1988; Sperling and Loevinsohn, 1993; Weltzien *et al*., 1996; Almekinders and Elings, 2001; Ceccarelli and Grando, 2007). In this vein Africa Rice Center (AfricaRice) has used PVS to improve the adoption of the NERICA varieties (Gridley *et al*., 2002). However, there is still little attention on the outcomes of farmer technology development and innovation, and ways to build upon these processes or to integrate them with scientific technology development.

Farmer technologies, such as farmer varieties, are the result of long innovation trajectories. These trajectories are shaped by interactions among agroecological, socio-economic and cultural factors and it is therefore essential to understand such interactions when involving farmers in technology development or building upon farmer technology development. The need for a more decentralized technology development approach (for, e.g., varieties) with a larger role for farmers has become even clearer (Dorward *et al*., 2007; Efisue *et al*., 2008; Nuijten *et al*., 2009; Mokuwa *et al*., 2012). For example, Mokuwa *et al*. (2012) provide evidence that farmer rice varieties can be widely adaptable, as a considerable number performed well under very different ecological conditions and are therefore not restricted to the locality where they were developed. This means that farmers, next to researchers, equally produce technologies that may be relevant for farming over large regions.

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In many regions, farmers carefully innovate, select and match technologies to local environmental conditions, looking for optimal interactions of technologies with agroecological, socio-economic and cultural factors. The ways farmers organize their farm management and livelihood strategies differ widely, even within small, well-defined regions. Often this variation reflects differences in the agroecological environment, societal organization, and cultural and socio-economic dynamics. We therefore need a better understanding of how technologies interact with the agroecological and socio-cultural environments. Comparisons within and between different areas and countries may yield useful insights into key aspects and mechanisms underlying these complex interactions in rice-farming systems in West Africa. Such comparisons will also provide insights into the way farmer technologies have been developed and how to link farmer technology development with science. For a better understanding of these complex interactions a wide range of scientific disciplines is needed, such as soil science, plant breeding, agronomy, crop physiology, chemistry, economics, anthropology, and communication and innovation studies. As today's farming is also shaped by the past, archaeology and history may also be important to understand the socio-economic and cultural aspects of these complex interactions.

Examples of Complex Interactions

In the examples below, we draw from research conducted on farmer management of rice crop diversity. For example, Teeken *et al.* (2010) show that variety adoption is not the result of 'rational' choice in the narrow sense of optimizing production for given agroecological and socio-economic conditions. Cultural factors (e.g. rituals, food preferences) and socio-political factors (e.g. conflict) play a crucial role in the adoption or rejection of new varieties. For example, in Ghana, Guinea and Sierra Leone people show a cultural preference for rice varieties with a red pericarp over varieties with a white pericarp, whereas in The Gambia, Guinea-Bissau and Senegal people prefer varieties with a white pericarp. Since the late 1950s, the cultivation of African rice (*Oryza glaberrima*) has decreased in Ghana, but its role in rituals has become more important. In The Gambia, a reverse process has occurred: while older women still consider African rice very important (e.g. they like to plant a little bit of it in a field of Asian rice in the belief that it ensures a good harvest) younger women consider African rice as something bad (as being little more than a weed). In southern Guinea-Bissau and Sierra Leone, countries both affected by long periods of armed conflict, the use of African rice has increased. In southern Guinea-Bissau, people appreciate African rice for its medicinal properties, tolerance to salinity, and slow digestibility, while in Sierra Leone farmers appreciate African rice mostly for its ability to grow on poor upland soils, and its short growth cycle in the 'hungry season'. In maritime Guinea, the use of African rice has been maintained as it helps households to achieve food sufficiency in an environment marked by severe economic crises – it is adapted to poor soils and it digests slowly, which reduces daily intake.

Cultural identity can also be associated with tools. A very widely studied identity marker is the fulcrum shovel plough used in mangrove-swamp rice cultivation in Senegal, Guinea-Bissau and Guinea (Linares, 1992; Sarró, 2009). Very small tools like a small harvest knife also function as identity markers, although perhaps less obviously so. Despite the fact that a sickle would increase the speed of harvesting, Mandinka women in The Gambia and Senegal strongly oppose its use. They consider the sickle a Jola tool. Among the Jola the sickle is used by men, although it may also be used by women. Jola women sometimes use a sickle for the harvesting of short-straw (modern) varieties. Some Mandinka women acknowledge that a sickle would make harvesting of short-straw varieties much easier, but still they resist its use. This resistance can be better understood if we realize that in the past sickle harvesting was sometimes violently resisted by some groups in coastal West Africa because it was seen to challenge egalitarian cultural values (Richards, 1996).

The examples given above show how rice technologies (varieties, tools and techniques) are shaped by various factors in very different ways. Technologies such as tools and varieties have different development pathways, but have in common the fact that they are shaped by both environmental and cultural selection pressures. In this chapter, we use variety choice to show how agroecological, socio-cultural and economic factors all influence technology development, use and adoption. Which varieties are chosen not only depends on which varieties best fit a farming system, but also on socio-economic dynamics and the roles different crops and varieties play in larger socio-economic and socio-cultural systems. An example from The Gambia may be used to illustrate this. Before 1970, farmers commonly grew varieties with different crop cycle durations and *O. glaberrima* was the first rice to harvest. With the decrease in rainfall in the early 1970s, varieties with an equally short duration were introduced from Casamance (Senegal). In that same period, labour became less available at household level for rice pounding and bird scaring in the rice fields. Together these factors have affected crop and variety preferences and therefore also the selection and development of crops and varieties by farmers. Farmers explained that more than a generation ago it was not considered difficult to pound (mill) *O. glaberrima*, as pounding fonio (*Digitaria exilis*) was considered even more difficult. Subsequently, most farmers abandoned fonio; moreover *O. glaberrima* is now considered very difficult to pound (Nuijten, 2005). Another example of how social change and access to labour can impact on varietal choice may be given from mangrove-rice farming in southern Guinea-Bissau. In colonial times, Thom and Atanhã were the most extensively grown varieties because of their high productivity and good cooking and eating characteristics. Social change after independence led to a reduction in their cultivation due to the difficulty of finding youth labour-groups willing to do the intensive threshing required for these varieties (Temudo, 2011).

Guinea-Bissau also provides an example of how market conditions may impact on farmer preferences and adoption of new varieties. Since the 1980s, farmers have been adopting cashew (*Anacardium occidentale*) as a cash crop, reducing rice production and relying progressively on the purchase of imported rice during the pre-harvest 'hungry' season. Some farmers with large cashew orchards stopped rice production altogether, other farmers reduced their portfolio, while yet others began to prefer more tasty varieties. However, the decrease in the price of cashew and increase in the price of imported rice has reversed this trend. There is now a renewed interest in non-tasty varieties with long digestion times. Among these varieties attracting renewed interest one can highlight the upland variety Maimuna, which Nuijten *et al.* (2009) identified as belonging to a group of 39 rice accessions representing farmer varieties resulting from hybridization between *O. sativa* and *O. glaberrima*. The exact origin of these materials is beyond current farmer memory. Farmer practices enable such hybridization and spontaneous back-crossing to occur in their fields. Conditions of war and drought have presumably stimulated the spread of these varieties, apparently because they have considerable adaptive plasticity under sub-optimal farming conditions.

Varietal traits also play a complex role in the adoption rate of new varieties. Social processes play a more important role in the adoption of some traits than others (Nuijten, 2005). Crop duration is an example of a trait that is closely linked with the social system. In various upland rice cultivation areas in West Africa, the common rice varieties are chosen in such a way that they are similar in crop cycle duration. One reason for this is the labour calendar. This factor prevails among upland farmers in Guinea. Another important reason in The Gambia, Guinea and Guinea-Bissau is bird scaring. If varieties differ in crop duration, the crops mature over a longer period and hence bird scaring requires more labour. Farmers who sow their rice much earlier or sow earlier-maturing varieties, run the risk of a complete failure due to birds, if they cannot organize proper bird scaring. This implies that if farmers want to adopt a new variety with a shorter duration, farmers will need to test this variety simultaneously as a group, to avoid the risk that birds will destroy the entire crop of a lone pioneer.

The adoption of new varieties often follows a pattern in which a single farmer will test a variety, and then give it to neighbours or family members for further testing. If they also like the new variety it may then be adopted by other farmers in the village, and spread to neighbouring villages. But for some traits, like crop cycle duration, a different way of testing varieties is required, and a critical mass of farmers involved from the outset. This implies that there is a social component in variety choice, and this social component needs to be properly evaluated if varieties are to be introduced effectively. Where adoption of better varieties requires changes in the farming system at village level (as is probably the case for bird scaring of early and long-cycle varieties), there is little to be gained by relying on seed transfer to a handful of (so-called) 'master farmers'. Instead, a group innovation approach is required.

Similar social dynamics apply to traits related to digestibility. In communities where there are strong preferences for 'heavy' varieties, which digest slowly and 'stay long in the stomach', the uptake of 'light' varieties may only be for certain specific purposes, such as to meet the needs of old or sick people. Substantial adoption of light varieties would require re-organizing the food system; in particular, the possibility of increasing the food intake either by the consumption of more rice, and therefore larger fields for which more labour would be needed, or through diversification of the diet, for which a larger range of crops would need to be cultivated with consequent re-organization of tasks and the labour calendar and related rules and rights. This also applies to varieties which cannot be kept long after cooking without becoming either mushy or too hard. In various West African societies, it is important to be able to offer strangers food at any time of the day, or to keep the food till the next morning and eat it as breakfast. These aspects need to be evaluated as part of any rice innovation strategy.

Perhaps paradoxically, a thorough social analysis may be less needed for a trait like taste, which is often seen as a 'cultural' variable. Taste is determined by social dynamics, but is also to an important degree the result of individual preferences. If a variety with a different taste is appreciated by only one farmer, it does not imply any disadvantage for its cultivation. Over time, it may (or may not) be adopted by other farmers. In any case, taste is evaluated differently according to circumstances. A good illustration is the positive evaluation given to certain rices with a poor taste by farmers in southern Guinea-Bissau that might elsewhere be rejected because of this poor taste. The lack of attractive taste is deemed to slow down consumption, and so prevents eating more than necessary in times of food shortage, such as during the pre-harvest season (Temudo, 2011). Equally, farmers in Guinea and northern Guinea-Bissau sometimes mix heavy, poor-tasting rice with very tasty varieties to slow consumption of stock.

These examples show that the preference for traits is not only related to environmental factors, but also to socio-economic, cultural and individual factors. Desired and unwanted traits are conceived in relation to the diversity of available crops and their varieties and thus the concepts of desired and unwanted traits are fluid (Nuijten, 2005). This probably also explains differences in outcomes of studies on the importance to farmers of yield and taste. Taste can only be an important criterion where crop varieties differ greatly in taste and the same can be said for yield (Nuijten, 2005).

Variety preferences and criteria may change over time. In the past, Gambian farmers preferred varieties that matured within the rainy season in order to have as long a growing season as possible. With increasingly erratic rainfall, many farmers now prefer early varieties, although they do not want varieties that mature too early (Nuijten, 2005, 2010). Farmers in a village in Cacheu (Guinea-Bissau) often said that the varieties grown in Casamance and The Gambia today are too early and require intensive bird scaring (Nuijten, unpublished observations, 2007–2008). In the past they grew these early varieties next to varieties with a longer crop cycle duration in the uplands, but were able to do so because children did the bird scaring on early rice while adults worked on other crops. Now that the children go to school, farmers prefer to grow varieties with similar duration in the uplands, so they can do bird scaring and harvesting at the same time.

For other traits, notably yield, genotype-by-environment (G×E) interactions at the local level play a crucial role. For farmers to adopt a new variety for its yield, this new variety needs to perform better than the varieties grown by them over the previous two or three seasons. Farmers do not use multiple replications (or advanced statistical analysis), but only single ones, which implies the yield difference needs to be substantial for a farmer to appreciate it enough to adopt the new variety. Famers may also test the new varieties in the worst part of their plots, and if they perform well there, then they feel they are sure to get good productivity and yield stability elsewhere (Richards, 1986; Temudo, 2011).

In addition to G×E interactions, social processes may play a role when many new varieties are introduced simultaneously in a community. In such a case the adopted variety may not be the best-performing variety, but the variety introduced through the largest or most influential socio-political network. Thus, knowing about these networks and how they are constituted – e.g. as networks of patrons and clients – is important for any successful seed innovation strategy (see Richards, 1986).

Furthermore, variety choice and preference are not the same. Farmers need to choose varieties that do well in the field, even though those varieties do not meet all their preference requirements (Nuijten, 2005). For example, Gambian rice farmers prefer tall rice varieties, but if only short varieties are available with the right crop cycle duration, they will work with short varieties. Women in The Gambia also say they like varieties with big grains, but (particularly in the uplands) the best-performing varieties (both farmer and modern) have small grains. In short, not all preferences count with the same weight. Preferences predict whether (say) a tall, bold-grained rice will do better among Gambian farmers than a rival short, small-grained variety, but cannot indicate whether the tall, bold-grained type will be adopted.

This implies that adoption curves of new varieties are likely to differ depending on particular traits of those varieties in relation to the farming system and the wider socio-cultural and agroecological context. Certain 'permissive' agroecological contexts (in a well-watered country such as Sierra Leone, for example) may allow the adoption of quite a wide range of varieties with different traits. Similarly, socio-cultural and economic conditions may reduce or enlarge the number of desirable varieties, and may narrow or enlarge the variation in traits considerably, for reasons as diverse as ethnic and religious preferences, presence of milling machines, modes of labour organization, and availability of cash income sources and cheap imported rice.

As a result, the uptake of the same new technology (a variety) may show different patterns in different farming systems due to the different agroecological and socio-cultural contexts: the S-curve describing the uptake of a single technology may be quite variable in gradient according to local variations in the configuration of the competing and converging variables. The initial slow growth phase may be slower or faster, and the steepness of the middle part of the curve may also vary. In some areas, the adoption rate of a promising variety may be 100%, while in other areas the same variety may have only a moderate or low uptake. Explanation of what works, where and why, can be quite hard or impossible in the absence of careful analysis of socio-cultural and socio-economic selection factors and their interaction with environmental factors.

Discussion

The implication of the factors described above is that a better understanding of the interactions among technologies, agroecological and socio-cultural factors may allow the development of technologies more suited to farmers' needs. It may also facilitate the distribution of farmer technologies across regions as otherwise diverse as West Africa. Farmer varieties are often considered to be adapted to the local context, whereas modern varieties are developed for wide adaptation.

Research comparing farmer varieties of African and Asian rice in trials in Guinea-Bissau, Guinea, Sierra Leone, Ghana and Togo, shows that many farmer varieties are widely adaptable in agroecological terms (Mokuwa *et al.*, 2012). However, a considerable number of these widely adaptable farmer varieties are not appreciated outside their cultivation zone for socio-economic and cultural reasons. Some farmer varieties are adapted to both the agroecological and the socio-cultural contexts. An example is a variety collected in Guinea-Bissau, called Untufa and belonging to a new interspecific rice type identified by Nuijten *et al.* (2009), that was appreciated by farmers in a case study area in Ghana for both agroecological and socio-cultural reasons (Teeken *et al.*, 2011). In our examples we focused on rice varieties. For other technologies, for example sowing and harvesting tools, or fallow management and postharvest management practices, the same dynamics are also likely to emerge when studied. Some practices may fit various agroecological contexts, but not the socio-cultural contexts. There may be little technology-by-environment interaction, but much technology-by-society interaction, or vice versa. Other practices may fit well across a range of agroecological and socio-cultural contexts (i.e. there is little or no interaction) or be limited to a few localities because there is strong technology-by-environment-by-society interaction.

It may thus be important to test locally developed technologies across the region and to assess whether they are plastic (i.e. have low technology × environment × society interaction effects) or applicable only in specific localities. Given the large diversity in farming systems, and agroecological and socio-cultural variables, conducting experiments together with a wide network of farmers may provide a better understanding of how the various interactions among these variables limit or stimulate the adoption of new (local and modern) technologies (Richards *et al.*, 2009). An important question is how farmer technology development can be better linked to scientific technology development (Offei *et al.*, 2010). An essential first step in achieving this linkage is to realize that farmer technologies need to be valued in a similar way to the technologies developed by scientific research (i.e. without prejudice). If they show potential they deserve region-wide dissemination.

Theoretical perspectives and methodological approaches

At this stage there is no theory that is capable of integrating all perspectives from the various disciplines of soil science, plant breeding, agronomy, crop physiology, chemistry, economics, anthropology, communication and innovation studies, archaeology and history. The examples described above show that both simple and complex interactions may occur. In one case an agroecological factor may play a dominant role, whereas in a seemingly comparable case within a different context cultural factors may be critical. Various researchers have suggested a more systematic or holistic approach in order to fit varieties better to the environment and management practices, and to appreciate complex genotype-by-environment-by-management interactions rather than trying to ignore them (Kronstad, 1996; Kropff and Struik, 2002; Desclaux *et al.*, 2008). The disadvantage of the term 'management' is that it is already the result of interactions among genotypic, environmental and socio-economic factors. Researchers working on participatory plant breeding (PPB) have suggested that the environment should also include socio-economic factors (Ceccarelli and Grando, 2007). To systematically compare and integrate technological, agroecological, socio-cultural and economic factors we suggest the following framework, based on the formula used to describe G×E interactions:

$$P = \mu + T + E + S + T \times E + T \times S + E \times S + T \times E \times S + \varepsilon$$

This framework tangibly brings together the technical, natural and social at the same level.[1] In the context of rice-farming systems, the meaning of the symbols is the following:

- P = outcome (a farming system, resulting from various interactions between a technology and the societal and environment factors)
- μ = a common factor for all farming systems (a common factor shared by all societies in terms of social dynamics and environmental conditions)
- T = technology effects (e.g. differences in performance between varieties)
- E = environment effects (a range of agroecological variables such as climate, soil, landscape, pests)
- S = society effects (socio-cultural and socio-economic; e.g. appreciation of pericarp colour or maturity in relation to the labour calendar, and the societal processes underlying these preferences)
- $T \times E$ = technology-by-environment interaction (e.g. research by Mokuwa *et al.*, 2012, shows strong responses to environment for some farmer varieties and hardly any response for others)
- $T \times S$ = technology-by-society interaction (e.g. varieties that are widely adaptable in agroecological terms are appreciated differently on the basis of how they fit within the farming system in regard to factors such as duration or pericarp colour)
- $E \times S$ = environment-by-society interactions (e.g. the cultivation of rice in different environments [upland or lowland] may be done

by various social groups depending on cultural regulations)

- $T \times E \times S$ = technology-by-environment-by-society interactions (specific outcomes as the result of interactions between all three terms)
- ε = residual variance, not accounted for by any measured factor or their interactions; it includes outcomes that are too complex to explain through reference to any identified mechanism, or behind which there is no particular intentionality other than farmer performance (see Richards, 1993; Batterbury, 1996). Richards (1989, 1993) calls the process of adjusting the farming decisions to ongoing opportunities and constraints 'performance'.[2]

Where appropriate, the factors *T*, *E* and *S* can be further broken down into relevant components. The nature of these factors depends on the research question. The factor ε is often considered unimportant in natural-science research, but in our view it is very important: it not only stands for random noise that is too complex to explain, but also for contexts that at some point in time may yield interesting innovations.

The best methodological approach to describe and/or measure $T \times E \times S$ interactions is a comparative case-study approach, combining experiments (applicable to both social and natural science aspects), questionnaires, various types of interviews, and observation-based and participatory approaches (Nuijten, 2011). Examples of this approach are studies on the development of a new rice type with an interspecific background (Nuijten *et al.*, 2009) and the variation in wide adaptability of farmer varieties (Mokuwa *et al.*, 2012). For a systematic integration of the various social and biological research methods, including qualitative and quantitative research methods (Fig. 29.1), the methodology known as technography (Richards, 2001; Jansen and Vellema, 2011) can be used as a framework. Technography (the description and analysis of technological activity as a systematically related set of material and sociological processes) assumes the existence of real (if deeply embedded) causal mechanisms of both a biological/material and sociological nature. Social facts are real but not necessarily material in constitution. Technography is located within a philosophical framework of critical realism, which assigns an equivalent epistemological status to social and biological variables (see Sayer, 2000). Although technography is in essence a social-science methodology, it can be integrated (because of its attention to causal mechanisms) with various biological research methods that have a strong focus on causal mechanisms and experimentation. The idea is not to generate a single data set of biological and sociological data, but to generate data sets in such a way that a range of hypotheses in relation to the actual functioning of a particular mechanism within a certain context can be validated.

Towards new models for technology development and dissemination

At this stage, there is insufficient data available for a systems approach for rice farming in West Africa. It is also argued that a disadvantage of a systems approach as currently practised is that it largely ignores power issues (inequality, gender, age, etc.) and the openness inherent in farming practices (Jansen, 2001). Another disadvantage is that there is little scope to consider performance, which is an essential element of (both low-input and high-input) farming.

A better understanding of the interactions among technology, environment and society elements is necessary to understand how to build new models for technology development and dissemination in which there is an active role for farmers. In this chapter we have provided some examples of such interactions, mostly in relation to variety choice. We need more examples relating to other technologies, such as soil and water management, and the control of pests and diseases. The local farming system needs to be taken as the starting point, using the suggested methodology to identify key interactions.

A comparison between sub-Saharan Africa and Asia may provide some useful insights in terms of technology development and adoption at a macro level. Certain differences exist in terms of institutional organization at the national level. For example, in China the state plays a dominant role in technology development, which is an important factor

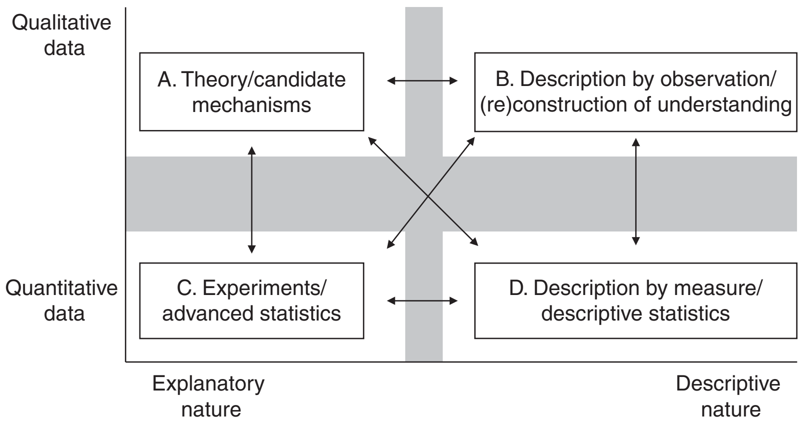

Fig. 29.1. Four basic research styles in the natural and social sciences, and humanities. (After Nuijten, 2011, with permission from Elsevier.)

explaining why China was the first country to develop hybrid rice (Shen, 2010). In India, many NGOs are involved in the promotion of new technologies, such as the System of Rice Intensification (SRI) (Glover, 2011). However, in sub-Saharan Africa the role of the state in agricultural and rural development has declined drastically since the mid-1980s, and many countries have undergone wars and civil conflicts with dramatic impacts on food security, seed security and technological development. NGOs in West Africa have taken up agricultural development only to a limited extent, often only for limited periods of time, and their agendas are influenced by the priorities of international donors. This sometimes results in contrary efforts, such as in The Gambia where some NGOs promoted tree planting in vegetable gardens developed earlier by other NGOs (Schroeder, 1997). More information is needed to better understand the differences in institutions and social contexts between Asia and sub-Saharan Africa.

To improve our understanding of why certain technologies replace others, to what extent and at what speed, the multi-level perspective (Geels and Schot, 2007) may be a useful way of explaining the importance of technographic methodology to technical scientists. The multi-level perspective helps to organize the material and sociological processes related to technological activity and, as such, may help open up the 'black box' of farming systems. In Fig. 29.2, three levels are identified: the socio-technical landscape (exogenous context), the socio-technical regime (the dominant practice) and niche innovations (other practices). The socio-technical regime is shaped by technology, culture, science, industry, market and policy, and adopts innovations developed in niches under certain conditions (Geels and Schot, 2007). The advantage of the multi-level perspective is that it helps to reveal the elements that constitute socio-technical regimes and how they are related to the wider context and to niche innovations. The multi-level perspective may be useful for illuminating strengths and weaknesses of various participatory approaches, and may possibly explain the relative lack of success of some of them. For example, several case studies on participatory approaches and farmer field school approaches in East Africa show that often the old extension approaches were continued using new labels (Isubikalu, 2007; Kamau, 2007). However, a difficulty of the multi-level perspective is where to draw the boundaries between the socio-technical regime, the wider socio-technical landscape, and the niches.

The multi-level perspective agrees with the idea that a broad base is needed for technology development, not only in terms of diversity, but also in terms of technology development pathways/networks. Such networks between farmers and scientists may be based on unsupervised learning, as both practice

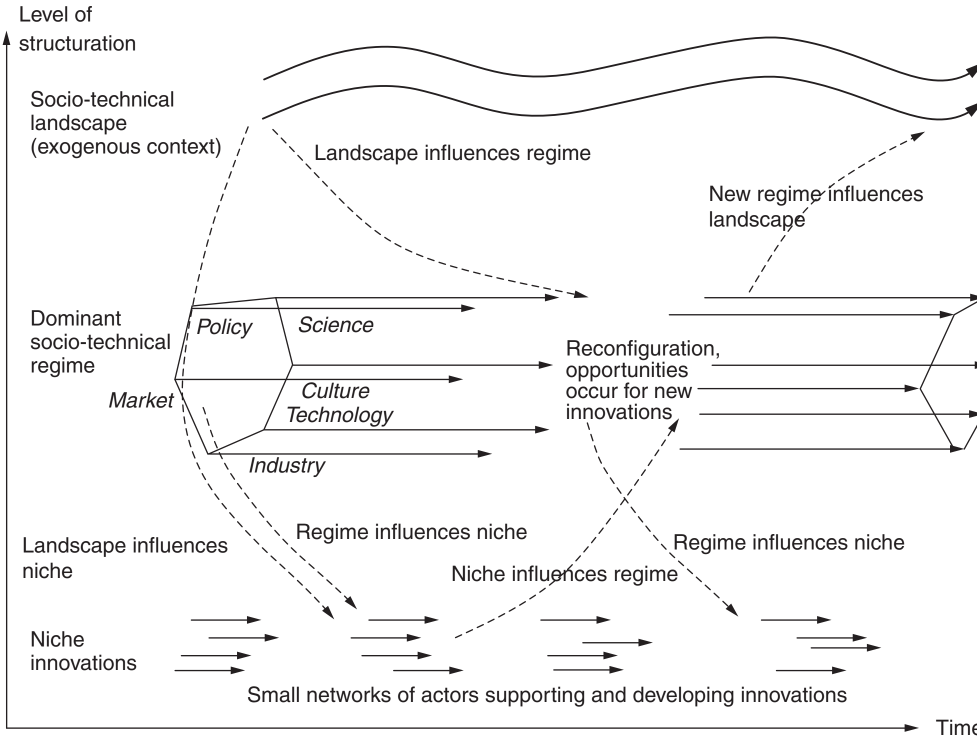

Fig. 29.2. Multi-level perspective. (Adapted from Geels and Schot, 2007.)

observation-based learning and thus no fundamental incompatibility exists between science and farmer innovation (Richards *et al.*, 2009; Offei *et al.*, 2010). However, scientists and farmers use different modes of communication. On-farm trials can be platforms for scientists and farmers to appreciate each other's ways of communication, to share their experiences and to learn from each other, using participatory and/or action-research approaches (Almekinders *et al.*, 2009; Bentley *et al.*, 2010). The trials can have different formats, differing in number of treatments and management, and still be suitable for advanced statistical analysis (Mutsaers *et al.*, 1997; Witcombe, 2002). Research has shown that farmers can handle large numbers of treatments (Ceccarelli *et al.*, 2001) and have a natural interest in experimentation (Richards, 1986; Bentley *et al.*, 2010).

The methodological approach we describe in this chapter facilitates a better understanding of farmer experimentation, and its outcomes, and how it is related to agroecological, sociocultural and economic factors (Nuijten *et al.*, 2009; Mokuwa *et al.*, 2012). With more studies of this kind, the multi-level perspective may more clearly illuminate what institutional adjustments at the level of science and policy are needed to facilitate more interaction and technology exchange between scientists and farmers.

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Notes

[1] At this stage, the framework cannot be used for sophisticated statistical analysis, but its advantage is that it can be used as an analytical framework to better understand how the technical, environmental and societal interact.

[2] Batterbury (1996) argues that planning and performance play different roles in different farming systems, depending on the agroecological and socio-cultural context (including political factors, e.g. conflicts and war). This implies that the factor ε may be smaller in the savannah zone (e.g. in Burkina Faso) where the rainfall period is short and farmers need to plan their farming activities much more, than in the forest zone (e.g. in Sierra Leone) where farmers have the opportunity to adjust their farming activities depending on constraints and opportunities offered by the agroecological and socio-cultural context.

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